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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

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In the Matter of	)	
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Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range	)	ET Docket No. 98-206 RM-9147 RM-9245
and	)	
Amendment of the Commission's Rules to Authorize Subsidiary Terrestrial Use of the 12.2-12.7 GHz Band by Direct Broadcast Satellite Licensees and Their Affiliates	)	

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COMMENTS OF PANAMSAT CORPORATION

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COMMENTS OF PANAMSAT CORPORATION

PanAmSat Corporation ("PanAmSat"), by its attorneys, hereby responds to the Commission's proposal to permit non-geostationary fixed- satellite service ("NGSO FSS") systems to use spectrum that is allocated on a primary basis to, and used extensively by, the geostationary fixed-satellite service ("GSO FSS").

BACKGROUND AND SUMMARY

INTRODUCTION

There is general agreement that NGSO FSS use of GSO FSS spectrum presents very serious sharing issues. Unless adequate technical and service rules are adopted to govern NGSO FSS operations — and unless the Commission enforces these rules vigilantly — NGSO FSS systems will impair communications over GSO FSS systems. PanAmSat, on its own behalf and on behalf of its existing and potential customers, therefore has a compelling interest in ensuring that the Commission adopts and enforces appropriate safeguards in this proceeding. PanAmSat is confident that the Commission will endeavor to take into account the needs of GSO systems when it adopts technical rules to govern NGSO operations.

Despite PanAmSat's concern about the potential for NGSO FSS interference, it does not oppose the Commission's proposal to permit NGSO FSS systems to operate in GSO FSS spectrum if the Commission adopts technical and service rules that protect GSO FSS systems from interference and requires each NGSO FSS applicant to demonstrate full compliance with these rules before receiving an FCC license.

In addressing the question of technical rules, PanAmSat concurs with the goals that the Commission established for itself in the NPRM: to develop an independent record in this proceeding and, based upon this record, to adopt aggregate power flux density ("apfd") limits and equivalent power flux density ("epfd") limits that will ensure that NGSO FSS systems do not impair existing or future GSO FSS operations.

<u>The Provisional WRC-97 Limits</u>

The Commission should not rubber stamp the provisional limits agreed to at 1997 World Radiocommunication Conference ("WRC-97"). Rather, the Commission should consider the substantial technical record that has been developed since the WRC-97 conference. In the past two years, technical experts have worked diligently in the ITU's Joint Task Group ("JTG") 4-9-11 to refine the WRC-97 provisional limits and transform them into adequate technical standards. As a general matter, these studies show that the WRC-97 limits are inadequate to protect GSO FSS communications, particularly in geographic areas with little rain. Moreover, the WRC-97 limits are "single entry" limits that ignore the probability that multiple NGSO FSS systems will be launched and placed into operation.

The JTG 4-9-11 has studied various methodologies for measuring the adequacy of potential epfd and apfd limits. Only one methodology should form the cornerstone of the Commission's analysis in this proceeding, because it alone provides a sound technical basis for evaluating NGSO/GSO interference. That methodology (presented by the United States at the third meeting of JTG 4-9-11) not only confirms the inadequacy of the WRC-97 provisional limit, but also can be used to determine acceptable minimum epfd and apfd levels that adequately will protect GSO FSS links.

Employing that methodology, the United States has developed new, proposed epfd and apfd limits to protect GSO FSS systems from interference originating from NGSO FSS systems. These proposed limits are set forth in Appendix A and represent the most up-to-date and technically substantive means of governing NGSO FSS use of GSO FSS spectrum. These limits also are achievable. At least some of the NGSO FSS applicants have proposed systems that meet all or most of these limits, demonstrating that the Commission need not jeopardize GSO FSS operations in order to make possible the deployment of NGSO FSS systems.

Multiple Interfering Signals

Defining appropriate epfd and apfd limits, moreover, will not complete the Commission's work. As noted above, only aggregate, multiple-entry limits meaningfully address the reality of GSO/NGSO sharing. Aggregate limits, however, must be allocated across all NGSO FSS systems that may be placed into operation (whether or not licensed by the FCC). There is not a linear relationship between epfd/apfd levels and the number of NGSO FSS systems. Developing an appropriate allocation methodology, therefore, is no easy task, but it is an essential pre-condition to licensing NGSO FSS systems.

In order to allocate aggregate interference levels across multiple NGSO FSS systems, the Commission will need information about both the maximum number of NGSO FSS systems that will be placed into operation and the technical characteristics of those systems. As a result, the development of an allocation methodology likely will be possible only as the Commission and foreign licensing authorities achieve additional progress in their consideration of NGSO applications.

Other Issues

Adopting aggregate and allocated interference limits is only part of the equation for protecting GSO FSS systems. The Commission also must develop and enforce a meaningful verification process if it is to achieve its goal of protecting GSO systems from objectionable interference.

Several other measures also are needed to protect GSO FSS systems from interference. First, the Commission should broaden its focus in this proceeding by adopting standards that will protect U.S.-licensed GSO FSS systems fully, whether they are operating inside or outside the United States. Second, the Commission should require NGSO systems to protect GSO FSS satellites operating in inclined orbits. Third, the Commission should grant GSO and NGSO systems equitable access to the 10.7-11.7 and 12.75-13.25 GHz bands. Fourth , the Commission should seek more information regarding the usage and protection requirements for large aperture earth stations. Fifth, the Commission needs to adopt standards that protect GSO FSS links not only during satellite launches, but at all times.

DISCUSSION

I. THE WRC-97 LIMITS DO NOT PROTECT GSO FSS SYSTEMS.

A. THE WRC-97 LIMITS ARE NOTHING MORE THAN PRELIMINARY "BEST GUESSES" BASED ON AN INADEQUATE TECHNICAL RECORD.

At WRC-97, a decision was reached to permit NGSO FSS systems to use certain spectrum that already was allocated to, and heavily used by, GSO FSS networks. This decision was premised upon the belief that technical standards could be developed that would protect GSO FSS systems from receiving objectionable interference from NGSO FSS networks.

Unfortunately, prior to WRC-97 the question of NGSO/GSO sharing had not been studied fully in the usual ITU Radiocommunication Sector ("ITU-R") study group process.[1] As a result, there was only an incomplete foundation upon which the conference could base technical standards. The participants at WRC-97, therefore, decided to proceed in a two-step fashion. They would make the NGSO FSS allocation at the 1997 conference but, effectively, would defer the adoption of technical limits to the next conference.

The WRC-97 conference did not remain completely silent on the question of technical limits. It adopted epfd and apfd limits on a provisional basis that were intended to protect GSO FSS networks from interference originating from NGSO FSS networks operating in shared bands. However, in recognition of the limited technical record upon which these provisional limits were based, the conference made clear that the limits were not, in any way, final. Rather, WRC-97 Resolution 130 specifically recognized the provisional nature of the WRC-97 limits and designated JTG 4-9-11 to study the question of NGSO/GSO sharing and review — and, as necessary, revise — those limits. Based upon this review, WRC-2000 would then adopt final limits to govern NGSO FSS operation in the shared bands.

Resolutions 130 and 538 also made clear that NGSO FSS systems would have to comply with the final limits adopted at WRC-2000, even if these limits differed from

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[1] See NPRM at ¶ 5.

the WRC-97 limits and even if information regarding NGSO FSS systems were submitted to the ITU, or NGSO FSS system were brought into use, prior to WRC-2000.[2] This requirement confirmed, in the most practical way possible, the provisional nature of the WRC-97 limits.

The WRC-97 epfd and apfd limits were nothing more than "best guesses" that were reached at a very preliminary stage in the study of NGSO/GSO spectrum sharing. Their existence is the product of a political, multi-lateral discussion process and in no way reflects a technical conclusion as to whether the limits could adequately protect primary GSO FSS operations from objectionable interference.

B. TECHNICAL DEVELOPMENTS SINCE WRC-97 DEMONSTRATE THE INADEQUACY OF THE WRC-97 PROVISIONAL LIMITS.

In accordance with Resolution 130, JTG 4-9-11 has spent the past two years studying the question of GSO/NGSO sharing. During this period, it was agreed that the allocation methodology of ITU-R 1323, as developed by ITU Working Party 4A, would serve as the basis for evaluating the adequacy of any set of proposed apfd and epfd limits. PanAmSat applied that allocation methodology to the WRC-97 provisional limits. Its analysis, which is reflected in the official United States submission to JTG 4-9-11 attached hereto as Appendix A[3], conclusively demonstrates that the WRC-97 provisional limits will not adequately protect GSO FSS links from objectionable interference.[4]

The inadequacy of the WRC-97 limits is most pronounced in dry regions. In areas with large rainfalls, GSO FSS satellite system operators dedicate extra power in order to provide a link margin that can accommodate rain degradations without driving a link's signal strength below its minimum acceptable level. While these margins were intended to deal with the problem of rain attenuation and customers pay for extra margin, NGSO FSS systems view this margin as a buffer to mitigate NGSO FSS interference.

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[2] See NPRM at n.13.

[3] The U.S. technical submission was presented to the JTG meeting in Long Beach on December 10th as Document 4-9-11/US62R2. At the meeting the document was re-numbered with international identification 4-9-11/342-E. In addition, two amendments to the document were made at the meeting. The document as it was considered at the Long Beach JTG meeting appears in its entirety in Appendix A.

[4] See Appendix A at Annex 3, Section 4.0 and Table 4-1, and Annex 4.

No similar buffer exists in low rainfall areas. In territories with little rainfall, the risk of rain degradation is not present and, therefore, satellite operators do not devote scarce power resources to create large link margins. As a result, on these more "sensitive links," there is little or no extra margin available and, therefore, no cushion available to mitigate NGSO FSS interference.

It is a truism that a chain is no stronger than its weakest link. One cannot operate a "global" system if the system is relegated to areas having adequate rainfall. Nor can one provide ubiquitous GSO FSS services when dry regions are subject to interference that eliminates link margins. While the WRC-97 provisional limits may be adequate to protect GSO FSS systems on links that already contain a relatively high link margin, Appendix A demonstrates that tighter limits are necessary to provide universal protection for GSO FSS communications networks.

C. THE WRC-97 LIMITS DO NOT TAKE INTO ACCOUNT THE IMPACT OF MULTIPLE ENTRY.

Even at the time of WRC-97, it was generally recognized that the provisional limits suffered from a second fundamental flaw. The WRC-97 limits are "single entry" limits: *i.e.*, they specify limits only for a single NGSO FSS satellite and do not consider the impact either of multiple NGSO FSS satellites within a system or of multiple NGSO FSS systems.[5]

There is no question that an NGSO FSS system will involve multiple satellites. In addition, at this time it appears likely that more than one NGSO FSS system will be launched and placed into operation: seven NGSO FSS systems have been applied for in the United States;[6] additional, foreign-licensed systems may transmit signals over North America even though they are not licensed to provide service within the United States; and other foreign-licensed systems operating outside North American may

[5] NPRM at ¶¶ 5, 72.

[6] On November 2, 1998, the Commission created a processing round for NGSO FSS applicants. "Cut-off Established for Additional Applications and Letters of Intent in the 12.75-13.25 GHz, 13.75-14.5 GHz, 17.3-17.8 GHz and 10.2-10.7 GHz Frequency Bands," Public Notice, Report No. SPB-141 (Int'l Bureau) (Nov. 2, 1998). Boeing, Denali Telecom, Hughes Communications, SkyBridge, Teledesic, and Virtual Geosatellite all filed one or more system applications on or before the specified cut-off date.

transmit signals in other regions in which U.S.-licensed GSO FSS satellite systems operate.

It is also generally recognized that the existence of multiple NGSO satellites, as well as multiple NGSO systems, will exacerbate the NGSO/GSO sharing problem. Within a single NGSO system, interference will be caused both by the main beam of the "primary" satellite (*i.e.*, the satellite serving the same area as the GSO FSS satellite) and by the side lobe beams of any additional satellite(s) in the NGSO constellation that are in view of the GSO FSS satellite or earth station. In addition, the existence of multiple NGSO FSS systems will have a cumulative effect that adversely will affect the NGSO systems' ability to share spectrum with other services.[7]

As the NPRM also recognizes, there is no clear or simple method for converting single-satellite, single-entry limits into aggregate limits that account for the interference potential of all NGSO satellites within a constellation and of all NGSO constellations that are placed into service.[8] Even if the WRC-97 provisional limits otherwise were adequate — which, as discussed above, they are not — their failure to account for the problem of multiple entry thus makes them fundamentally ill-suited for use by the Commission.

D. THE WRC-97 LIMITS WILL LIMIT GSO EXPANSION OPPORTUNITIES AND LEAVE SOME GSO OPERATIONS UNPROTECTED.

As the Commission acknowledges in the NPRM, the WRC-97 provisional limits may not protect incumbent operations from interference and may not preserve their opportunities for future development. Most fundamentally, in discussing the need for strict NGSO FSS financial qualification standards, the Commission acknowledged that NGSO FSS operations could constrain the development of one or more existing services.[9] PanAmSat thus believes that adoption of the WRC-97 limits would be inconsistent with the Commission's express intention to protect existing and future GSo FSS operations.

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[7] NPRM at ¶ 72.

[8] See NPRM at ¶ 72.

[9] NPRM at ¶ 85 ("[e]ven if there were only to be one [NGSO FSS] applicant ..., grant of a license to an underfinanced applicant might preclude or limit expansion by existing operators [who currently use Ku-band spectrum]....") (emphasis added).

The Commission also has acknowledged that the WRC-97 limits will not protect certain specific types of GSO FSS operations from receiving harmful interference. For example, the Commission recognized that NGSO FSS systems likely cannot share spectrum on an interference free basis with large aperture antennas used in GSO FSS earth stations.[10] Similarly, the Commission acknowledges that NGSO FSS systems could seriously interfere with GSO FSS TT&C links used during the launch (or transfer orbit) phase, even if they are operating in accordance with the WRC-97 limits.[11] Thus, the WRC-97 limits, if adopted, will leave GSO FSS operations vulnerable or compromised in at least two important areas.

E. <u>In Light Of The Defects Discussed In The Above Subsections, The Commission Should Abandon Its Proposal To Adopt The WRC-97 Limits.</u>

Adoption of the WRC-97 provisional limits would not serve the public interest. As demonstrated above, the WRC-97 limits are inadequate to protect GSO FSS systems from interference caused by NGSO FSS networks. There is, therefore, an inconsistency between what the Commission is trying to achieve and what it has proposed.

The Commission correctly establishes in the NPRM the fundamental premise that should underlie any decision in this proceeding: that if NGSO FSS systems are to be allowed to use GSO FSS spectrum, they should do so in a manner that will not cause interference to GSO FSS systems or hinder the future development of the GSO FSS service.[12] The Commission also recognizes other crucial facts: that the WRC-97 limits are provisional and were adopted without an adequate technical foundation;[13] that the WRC-97 limits will not fully protect GSO FSS operations;[14] and that the

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[10] NPRM at ¶ 27 and n.51. GSO FSS large aperture earth stations are more sensitive to interfering NGSO FSS signals. It has been proposed that epfd and apfd limits will be set at a level that protects antennas only up to a certain diameter. While NGSO FSS operators will be required to protect existing antennas that exceed this diameter through individual coordinations, NPRM at ¶ 27, the FCC has proposed to provide no protection to subsequently added large antennas. As a result, the Commission will make it difficult or even impossible for GSO FSS users to employ large aperture antennas in the future. <u>See</u> Section V.D, *infra.*

[11] NPRM at ¶ 29.

[12] NPRM at ¶ 1.

[13] NPRM at ¶ 5.

[14] <u>See</u> Section I.A, *supra*.

United States uses the Ku-band in a "unique and extensive" manner and, therefore, that it is "essential" that the Commission develop an independent record in this proceeding and, based upon this record, develop and adopt technical limits and spectrum sharing criteria that adequately protect U.S.-licensed NGSO FSS operations.[15]

Adopting the WRC-97 provisional limits, however, will not accomplish these objectives. The Commission, therefore, should reevaluate its approach by taking into account the technical information that has been developed post-WRC-97, and in particular the analysis that is set forth in Appendix A.

II. THE EPFD AND APFD LIMITS SET FORTH IN APPENDIX A WOULD PROTECT GSO FSS OPERATIONS.

A. THE LIMITS SET FORTH IN APPENDIX A ARE TECHNICALLY JUSTIFIED.

As discussed in the previous Section, JTG-4-9-11 and ITU Working Party 4A[16] spent well in excess of a year developing an agreed-upon methodology for allocating NGSO interference into GSO networks. This achievement is important not only because it provides a basis for documenting the inadequacy of the WRC-97 limits. More importantly, it also provides a basis for developing a set of alternative, acceptable limits, using an approach that has been endorsed by the U.S. preparatory group charged with studying NGSO/GSO sharing.

Appendix A discusses in detail the approach used to analyze the GSO protection requirements and develop its revised recommended limits. To summarize briefly, candidate epfd and apfd limits were derived using the criteria described in ITU-R Preliminary Draft New Recommendation 4A/TEMP/66, which proposes a compact method for calculating permissible levels of interference from NGSO networks into GSO networks operating in the same spectrum bands. The candidate limits then were verified by using the 10% criteria, as defined in Recommendation ITU-R 1323 Recommends 3.1 and Equation 2 of this document, first described in Document JTG 4-9-11/111 and incorporated into Document WP4A/TEMP/66. Using the 10% criteria of Rec. ITU-R 1323, the limits were tested against the GSO link

[15] NPRM at ¶ 11.

[16] Because of the magnitude of the work involved in preparation for WRC 2000, over the past year and a half the ITU Working Party 4A meetings have primarily been continuations and supplements of the JTG meetings.

budgets given in Annex 1 and Annex 2 of Document 4-9-11/TEMP/29. These were provided in response to an ITU general request appearing in their Document CR/92 asking all administrations to provide information to the JTG about their sensitive link budgets.

Appendix A also tested the candidate limits against specified "sensitive links" (*i.e.*, as discussed in the previous section, links using little or no excess transmission power levels beyond that required to compensate for normally expected signal attenuation due to rain.). The sensitive links were identified from a universe of computer generated links that were designed to serve city pairs taken from a world wide data base of cities that had significant populations. Each link was then examined for its interference sensitivity. Every linked was designed to operate and perform with generic parameters similar to those contained in TEMP/29 Annex 1. All links were then tested with the candidate epfd or apfd level and if a candidate limit accounted for more than 10% of the unavailability for any sensitive link, the link was considered to have failed the verification procedure. A new candidate epfd or apfd limit was then selected for a subsequent test. The verification process was completed only when all links passed the 10% test. The final candidate apfd and epfd levels, used in the test where all links passed, were then considered as being the acceptable limits.

Use of the 10% criteria was intended to ensure that GSO system operators and users do not shoulder the burden of mitigating NGSO interference. A GSO network can operate in the presence of interference levels that exceed the 10% criteria only by devoting more power to the affected link(s). Because on-board power is a scarce resource, such an outcome directly and adversely affects GSO operators and customers.[17] Consequently, it violates the condition that NGSO systems be allowed to use GSO spectrum only if they can operate without harming present or future GSO system operations. Future FSS operations must include the possibility of implementing new services with, for example, more spectrum efficient technologies; and, having the ability to provide existing and new services to locations currently unserved from either existing or future satellites.

[17] GSO system users generally are charged not only for the bandwidth used, but also for the power level dedicated to support their communications links. As a result, any outcome that forces GSO satellite operators to dedicate more power to individual links will have a direct effect on GSO end users.

In addition to using an appropriate unavailability standard, the Appendix A analysis is unique in that it fully considers the problem posed by sensitive links. As discussed in Sections 1 and 3.2 of Appendix A, *supra*, GSO FSS links with little or no rain margin are particularly susceptible to NGSO interference. The international study group process, however, has not adequately examined the problem of sensitive links primarily because it has relied exclusively on data submitted by only a few countries. Most countries and regions in which a large number of sensitive links exist — including Russia, China, northern Africa, and the Middle East — did not submit data on these links to JTG 4-9-11.[18] As a result, any analysis that relied on the JTG's data paid scant attention to the needs of national and international systems serving many of the areas where the most sensitive links could occur.

In order to assess the interference potential of NGSO networks adequately, one must augment the data on "sensitive links." Appendix A does this and, in so doing, stands alone in terms of technical completeness.

The FCC should address the problem posed by sensitive links, whether or not those links lie outside the United States and whether or not data on those links was submitted by a national authority to the JTG. Because the United States is the licensing authority for PanAmSat and is responsible for coordinating Intelsat's satellites within the ITU, the FCC needs to take into account the requirements of global systems. It can do this only if it adopts epfd and apfd limits that protect all links — including sensitive links — from receiving harmful interference.

Appendix A explains and justifies in detail the technical basis for the epfd and apfd limits it proposes. It takes into consideration the unique and extensive use of the GSO FSS bands by U.S.-licensed systems. It is based upon a 10% interference allocation methodology that has been approved not only by the international body charged with studying NGSO/GSO sharing, but was primarily supported by the NGSO industry. As an official U.S. submission to JTG 4-9-11, it already has been vetted domestically and received the imprimatur of the United States government. Finally, because Appendix A specifies aggregate limits it overcomes the "single entry" problem presented by the WRC-97 provisional limits. In light of these factors,

[18] The United States is the only country with a large number of sensitive links that submitted adequate data to the JTG.

the Appendix A limits reflect the most technically sound and reliable proposal before the Commission.

It should be noted that the limits set forth in Appendix A do not protect GSO FSS systems fully from NGSO FSS interference. In the interest of responsible spectrum sharing and in recognition with the technical difficulties NGSO systems could experience in trying to meet fully protective limits, however, PanAmSat is prepared to be flexible and in this vein, PanAmSat supports the U.S. proposal to the third JTG meeting, which goes a long way towards balancing all requirements. Thus, GSO FSS systems are willing to share and further explore with NGSO FSS interests the burden of opening the Ku-band to NGSO FSS networks.

B. THE LIMITS SET FORTH IN APPENDIX A ARE ACHIEVABLE.

The limits proposed in Appendix A are fully consistent with the needs of the NGSO industry. Several of the applicants in the Commission's first NGSO processing round have already proposed to operate within or near the protection levels reflected in Appendix A, thereby demonstrating that these limits are reasonably achievable and will not impede the development of NGSO systems.

Every class of NGSO applicant can and should achieve the necessary levels of protection: NGSO applicants who also operate GSO FSS systems and, therefore, fully respect the need to protect GSO FSS operations; NGSO applicants who have designed their systems relatively recently and, therefore, have incorporated the best available information on methods for protecting GSO networks into their system designs; and NGSO applicants who otherwise are willing to accept their responsibility to operate without harming GSO FSS networks.

The FCC should seize the opportunity to reward NGSO applicants who have designed systems that truly can share spectrum with incumbent GSO FSS operations. To this end, it should adopt apfd and epfd limits that are grounded in sound engineering analysis and proceed promptly to consider the applications of any NGSO first processing round applicant proposing operations that can meet or exceed these limits.

The Appendix A limits appearing in Addendum 2, therefore, present the Commission with a unique opportunity. Because GSO FSS operators have agreed that they are acceptable, and because some of the NGSO FSS applicants have certified that they are achievable, they reflect a consensus alternative that will make possible the rapid adoption of technical standards for NGSO FSS networks.

C. THE APPENDIX A LIMITS ARE CONSISTENT WITH THE UNITED STATES INTERNATIONAL COMMITMENTS.

The NPRM correctly concluded that the United States' commitments under the World Trade Organization Basic Agreement on Telecommunications do not prevent the Commission from adopting technically justified rules to address spectrum availability and sharing concerns.[19] As long as the Commission enforces these rules in a non-discriminatory manner — as its has proposed to do — the adoption of NGSO FSS technical and service rules is fully consistent with U.S. international commitments.

III. THE COMMISSION SHOULD ADOPT AGGREGATE EPFD AND APFD LIMITS AND SHOULD SCALE THOSE LIMITS TO REFLECT THE NUMBER AND CHARACTERISTICS OF INDIVIDUAL NGSO SYSTEMS.

In the NPRM, the Commission correctly notes that if multiple NGSO FSS systems operate within a band, the cumulative effect of their emissions will have a material affect on the viability of NGSO/GSO sharing.[20] Accordingly, it is essential that the Commission adopt aggregate epfd and apfd limits and develop a reliable methodology for allocating these aggregate limits across individual systems.

As the Commission recognizes in the NPRM, it is difficult to allocate aggregate interference limits across NGSO systems without knowing the number and technical characteristics of the specific NGSO FSS systems that are to be launched and placed into operation.[21] This fact makes it important for the Commission to link its actions in this proceeding to its actions in the NGSO first processing round and to its individual licensing actions.

Specifically, the Commission should defer any decision on an allocation methodology until it has reached a preliminary set of conclusions in its processing round proceeding and, thereby, has identified with reasonable certainty the domestic

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[19] NPRM at ¶ 12.
[20] See NPRM at ¶ 72.
[21] NPRM at ¶ 72.

systems that are eligible for licensing. In addition, the Commission should account for foreign-licensed systems that may be placed in service.

The Commission should not proceed based upon assumptions about the number of systems that might be placed into operation or the likely characteristics of those systems.[22] Such an approach is almost certain either to harm either GSO FSS systems (by underestimating the number of NGSO FSS systems) or NGSO FSS systems (by overestimating the number of NGSO FSS systems) and would not materially speed the deployment of NGSO FSS systems.[23]

In addition, the Commission should not issue any NGSO FSS license until it has adopted aggregate interference limits and an allocation methodology. On such a fundamental sharing question, it would not be appropriate to license systems before finalizing the underlying rules that will govern their operations.

Finally, the Commission should include in each NGSO FSS license the licensee's allocated share of the aggregate interference limits and an express condition that the licensee not exceed its individualized interference limit. This is particularly appropriate in light of the NPRM's proposal for defining "objectionable" interference, which depends exclusively on compliance with the technical limits: an NGSO system operating in compliance with the limits would be deemed not to be causing objectionable interference, while an NGSO system that fails to comply with the limits would be deemed to be causing unacceptable interference.[24] Under such a regime, it is essential for the Commission clearly and expressly to mandate the interference criteria that apply to each individual licensee's system and, thereby, to facilitate the resolution of any interference problems that arise.

IV. THE COMMISSION SHOULD ADOPT AND ENFORCE A RELIABLE, RIGOROUS VERIFICATION METHODOLOGY.

NGSO FSS systems represent an expensive, new and largely unproven technology. The precision requirements and resulting complexity of those systems

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22 See NPRM at ¶ 73.

23 Because the Commission already has opened a processing round for NGSO FSS systems, the universe of possible U.S.-licensed systems already has been defined and the Commission is in a position promptly to move forward in determining which of the applicants are qualified to receive a license.

24 NPRM at ¶ 28.

raises risks of their not being able to meet their required performance standards when put into actual operation. That, in turn, raises the concerns that once an NGSO system becomes operational it will be difficult to mitigate unacceptable interference that might affect GSO networks. Accordingly, NGSO compliance processes need to be rigorous with reproducible results that can be verified by the FCC and GSO operators.

The Commission, therefore, should insist that all theoretical design considerations addressing interference mitigation performance be fully disclosed. This is especially true for technologies, methodologies, principles and components associated with NGSO satellite and earth station antennas, interference mitigation techniques and earth station tracking and diversity switching algorithms. The Commission should require disclosure of all theoretical design principles relating to the meeting of performance objectives in sufficient detail to allow their accurate computerized simulations. This should be followed be complying laboratory measurements of all antenna structures in their most critical deployment.

With regard to the verification by simulation requirement, PanAmSat believes that it would be in the best interest of the U.S. if the FCC developed its own publically available software tool for the verification process. PanAmSat is of the opinion that normal technological progress will cause change that can not be anticipated in a static software tool and that the U.S. may have unique and changing sovereign interests in various aspects of verification and simulation that are not supported internationally. In order to insure the flexibility it may need the U.S. should consider creating a software vehicle over which it had control and could therefore change as it was needed. While many or all aspects of the JTG software may be useful to the U.S. as a starting point, the FCC should not adopt the JTG software as its verification tool. In order to develop the FCC software tool, the FCC might wish to rely on input from an industry group.

The Commission also should take into consideration that operational NGSO systems need to be verified and tested for compliance. This might be accomplished from monitoring and control locations that each NGSO network would normally establish with NGSO satellite compliance monitoring as one of its functions. Over time those stations would accumulate satellite pfd performance information that could be compared with simulated results to verify that the operational system performed as required. Considering the ongoing importance of that information, it would be advisable to require that compliance reports be provided to the Commission on a monthly or quarterly basis.

PanAmSat has no problems per se with the Commission's proposed definition of a gateway station.[25] However, it is concerned that later interpretations of that definition may allow a proliferation of other than intended applications into the gateway bands. For that reason PanAmSat would support a proposal for a minimum size earth station (say 3 meters) in order to reduce the economic attractiveness of other applications.

With regard to the Commissions request for comment on a proposed change in the definition for apfd[26] PanAmSat agrees that the current definition may somewhat overestimate the number of NGSO earth stations contributing to the apfd level for a particular GSO satellite. However it should be understood that there are many Ku band satellites that have large beam area coverage, i.e., with larger beam angles and those satellites must also be protected. Accordingly, PanAmSat believes the current definition should remain in order to protect those more susceptible networks

V. THE COMMISSION'S NGSO TECHNICAL RULES SHOULD REFLECT AND CONFIRM CERTAIN ADDITIONAL PRINCIPLES.

A. EPFD AND APFD LIMITS THAT ARE SUFFICIENT TO PROTECT GSO FSS NETWORKS SHOULD APPLY TO ALL BANDS IN WHICH GSO FSS SYSTEMS OPERATE.

In the NPRM, the Commission engages in a band-by-band analysis of its proposed NGSO FSS technical criteria. For each band, the Commission reviews the Region 2 allocation(s) and the actual, existing usage of the band in the United States. Based upon this review, the Commission proposes NGSO FSS technical criteria that, it asserts, will protect incumbent U.S. users of each band from interference.

In focusing solely on a band's domestic usage, the Commission has defined its role too narrowly. NGSO FSS systems will operate globally; similarly, U.S.-licensed GSO FSS systems operate outside the United States. In defining the technical criteria U.S.-licensed NGSO FSS satellites must meet, therefore, the FCC should consider all

[25] NPRM at ¶ 15
[26] NPRM at ¶ 37

ITU allocations — not only Region 2 allocations — and all existing and potential uses — not only domestic U.S. uses — for each of the bands in which the FCC has proposed to permit NGSO FSS satellites to operate.

For example, the 12.2-12.7 GHz band is allocated in Region 2 to the broadcasting-satellite service and, within the United States, this band is used primarily for the provision of DBS services.[27] As a result, the NPRM proposes to adopt epfd limits for the band that are that are based upon the needs of DBS receivers and other DBS applications.[28]

U.S.-licensed GSO FSS systems, however, rely heavily on the 12.2-12.7 GHz band outside the United States. For example, PanAmSat uses the 12.5-12.75 GHz band for communications in Europe, Africa, the Middle East, and Russia. Indeed, 12.5-12.75 GHz is the only Ku-band spectrum that is allocated exclusively to the FSS within Region 1 and, as a result, is a vital resource for U.S. GSO FSS licensees. Similarly, the primary GSO FSS band in the Pacific Rim is the 12.2-12.75 GHz band. PanAmSat, for example, uses this band for communications throughout Australia, Japan, and Southeast Asia.

In order to protect adequately the operations of U.S.-licensed GSO FSS systems, the Commission must broaden the NPRM's focus. Rather than adopting technical rules that address only domestic services, the Commission should develop NGSO FSS epfd/apfd limits that protect its GSO FSS licensees without regard to where they operate or what FSS frequencies they use.

B. THE COMMISSION SHOULD PROTECT GSO FSS SATELLITES OPERATING IN AN INCLINED ORBIT.

Under the Commission's rules, a GSO FSS satellite operator may extend the useful life of an existing satellite by operating that satellite in inclined orbit — *i.e.*, by maintaining its original east-west but not its north-south stationkeeping and, thereby,

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27 NPRM at ¶ 55. The band also is allocated to the fixed service. However, because point-to-point fixed systems licensed in this band after September 9, 1983 must operate on a non-interference basis with respect to the DBS service, the Commission is concerned primarily with protecting DBS links from NGSO FSS interference. See NPRM at ¶¶ 55-62.

28 Id.

conserving the satellite's remaining fuel.[29] By electing to employ an inclined orbit, the operator does not relinquish its rights as a primary, licensed user of the FSS spectrum: like any other GSO FSS satellite, an inclined orbit satellite is a primary user of the spectrum and is entitled to protection as such.[30]

Yet the NPRM proposes to relegate certain inclined orbit satellites to second-class status in order to promote the development of NGSO FSS systems.[31] Under the NPRM's proposed approach, GSO FSS satellites would have no protection from NGSO FSS interference if they exceed a certain, as yet undecided, degree of inclination.[32] This proposal effectively would preclude GSO FSS operators from employing higher degrees of inclination than the stated limit.

PanAmSat is concerned by the open-ended nature of the NPRM's proposal, which threatens to place an unreasonable burden on GSO FSS operators and users. It must be recognized that, by forcing GSO FSS operators to limit the degree of inclination, the Commission would increase satellites' fuel consumption and reduce operators' ability to use inclined orbit operations to extend a satellite's useful life. This, in turn, would increase the cost of GSO FSS capacity and burden users with more frequent network modifications.

It also must be recognized that imposing an effective limit on the degree of inclination would be inconsistent with the fundamental premise underlying the proposal to permit NGSO access to FSS bands. NGSO proponents contend that their systems can operate without causing interference to FSS systems, and it is on this basis that they have sought access to the FSS bands.[33] Yet when it comes to inclined orbit satellites, they seek to shift the burden of accommodation onto the existing, primary users.

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29 47 C.F.R. § 25.280. The Commission's rules do not limit the degree of inclination that may be used.

30 The Commission's rules governing inclined orbit operation grant to inclined-orbit satellites the same level of protection from interference as are granted to non-inclined-orbit satellites. See 47 C.F.R. § 25.280(b).

31 NPRM at ¶¶ 28, 36.

32 Id.

33 See, e.g., NPRM at ¶ 2 (the SkyBridge Petition for Rulemaking sought access to GSO FSS spectrum on the conditions that NGSO FSS systems would cause no noticeable degradation to GSO quality of service or availability and would impose no operational constraints on GSO systems).

Despite the fact that GSO FSS satellites operating in an inclined orbit are primary users of the FSS bands and, as long as they operate in accordance with the Commission's rules, are entitled to the same level of interference protection as other GSO FSS satellites, PanAmSat acknowledges that reasonable limit — to be determined on the basis of further evaluation — on the degree of inclination may be necessary. A reasonable limit will appropriately balance the needs of GSO FSS system operators against the interests of NGSO applicants. Anything less, however, would impose an unfail burden on the bands' existing users and should be rejected.

C. THE COMMISSION SHOULD TREAT GSO SYSTEMS AND NGSO SYSTEMS EQUITABLY WITH RESPECT TO DOMESTIC USE OF THE 10.7-11.7 GHZ AND 12.75-13.25 GHZ BANDS.

Under the Commission's current rules, only "international" GSO FSS systems are allowed to use the 10.7-11.7 GHz and 12.75-13.25 GHz bands.[34] This restriction was promulgated because, at the time of its adoption, it was believed that extensive use of these bands by the GSO fixed-satellite service could adversely affect the fixed service's ability to continue using the band.

In the NPRM, the Commission reasserts the perceived need to limit earth station deployment in the 10.7-11.7 GHz and 12.75-13.25 GHz bands,[35] a position with which PanAmSat disagrees but does not challenge in these comments. PanAmSat does, however, strongly object to the Commission's proposed solution to the alleged problem: to permit NGSO systems, but not GSO systems, to use the bands for domestic communications.[36]

The Commission should not place NGSO systems in a preferred position by giving them — but not GSO systems — access to the 10.7-11.7 GHz and 12.75-13.25 GHz bands for domestic purposes. Such a solution is harsher than necessary to achieve the Commission's goals and, therefore, would not serve the public interest.

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[34] 47 C.F.R. § 2.106 and n. NG104. In light of the Commission's elimination of the distinction between domestic and international satellite systems, the Commission now interprets NG104 as limiting GSO FSS systems to using this spectrum for "international" communications.

[35] NPRM at ¶¶ 17, 33.

[36] NPRM at ¶¶ 17, 33.

Rather than granting NGSO systems broad rights to use the 10.7-11.7 GHz and 12.75-13.25 GHz bands while denying these rights to GSO systems, the Commission should design rules for each service that balance the satellite service's need to use the band against the terrestrial service's interest in avoiding broad-scale earth station deployments. Such an approach would treat GSOs and NGSOs equitably while satisfying the justification underlying the NG104 restriction.

The Commission should not, however, simply subject GSO systems to the same rules that govern NGSO systems operating in the NG104 bands.[37] The Commission's proposed definition of "gateway operations" was written to describe one component of an NGSO network and does not translate well to the GSO context.[38] There are a variety of GSO FSS networks that employ a very small number of large earth stations but may not fall within the NPRM's proposed definition of "gateway operations." The following all are examples of such networks: a TT&C network involving one or two earth station facilities; a network linking a small number of video programming production sites to a central programming distribution center; a corporate network supporting high-bandwidth communications between a limited number of facilities; or a satellite-based Internet backbone network involving a discrete number of earth stations facilities.

Each of these applications involves the deployment of only a small number of earth stations and, thus, satisfies the Commission's goal of limiting earth station deployment in the NG104 bands. Were the Commission to restrict GSO FSS use of the NG104 bands to "gateway operations," it therefore would unnecessarily restrict GSO FSS use of the band.

Similarly, NGSO FSS system operators enjoy a great deal of flexibility in siting their gateway facilities: there is no need for them to place these facilities in urban areas. In contrast, GSO FSS networks often require the integration of existing sites, such as video production facilities, corporate offices, or Internet access points. As a result, while it is reasonable to direct NGSO FSS licensees to locate their gateways

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[37] See NPRM at ¶ 33 (requesting comment on whether to permit domestic GSO FSS gateway operations subject to the qualifications proposed for NGSO FSS operations).
[38] The NPRM proposes that gateway operations be defined "as earth station operations that are not intended to originate and terminate traffic but are primarily intended for interconnecting to other networks." NPRM at ¶ 15.

outside urban areas, it is unreasonable to impose a equally strict restriction on GSO FSS earth station applicants.

In light of the above considerations, the Commission should permit GSO FSS systems to use the NG104 bands for domestic communications under conditions that are equitable in comparison with — but not identical to — the rules that govern NGSO FSS use of the bands. Specifically, the Commission should require GSO FSS systems to comply with existing technical rules and prior coordination procedures.[39] In addition, it should adopt a presumption that GSO FSS domestic communications will be permitted if the earth station(s) to be used are limited in number and are located outside any "exclusion area" adopted for NGSO gateways operating in the 10.7-11.7 GHz band.[40] Finally, the Commission should authorize, on a case-by-case basis, domestic applications that do not meet these criteria but that otherwise are consistent with the policies underlying the rules giving NGSO FSS systems access to the NG104 bands for domestic communications.[41]

D. THE COMMISSION SHOULD REEVALUATE ITS TENTATIVE APPROACH FOR PROTECTING LARGE APERTURE GSO EARTH STATION ANTENNAS.

Large aperture GSO FSS receive antennas are more sensitive to interference from NGSO FSS systems than are antennas with a smaller diameter. As a result, NGSO FSS proponents have sought to limit their obligations with respect to large-diameter antennas by proposing the adoption of epfd limits that protect antennas up to a certain, specified size (*e.g.*, 10 m.) and the use of coordination procedures to protect existing antennas that exceed this size.[42] Any newly-deployed antennas that exceed the size protected by the epfd limits, however, would be forced to accept any interference received from an NGSO network.[43]

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[39] See NPRM at ¶¶ 20, 21.

[40] See NPRM at ¶¶ 23-25.

[41] For example, the Commission should permit the use of a GSO FSS earth station facility that is located within an "exclusion area" if the applicant demonstrates a need to locate the earth station facility within the exclusion zone, fully coordinates the facility with existing FS facilities, and demonstrates that the earth station's existence will not unreasonably constrain future FS use of the 10.7-11.7 GHz band.

[42] See NPRM at ¶ 27.

[43] See NPRM AT ¶ 28 (an NGSO system operating in compliance with the final technical rules adopted in this proceeding would be deemed not to be causing "unacceptable" interference to an incumbent user).

Large aperture GSO FSS receive antenna often perform communication functions that simultaneously serve many end users . For example, gateways into terrestrial telephone systems, cable system head ends, and VSAT and Internet network centers are often served by large antennas. Accordingly, excessive interference into those networks can affect a large number of users dependent on the availability of those services. Moreover, since their susceptibility to interference is greater, they are more apt to experience losses of synchronization of digital services applications connected to those networks. Synchronization loss of a radio path in a telephone network could result in a large number of users having to redial dropped connections. Similarly, sync loss in a cable or broadcast feed could cause loss of video information to a large viewing audience. Also, sync loss in an Internet or VSAT center could result in a large number of Internet connections to be dropped or the need to re-send data to a large number of links in VSAT networks.

Synchronization loss is a serious consideration for another reason. Sync loss between a satellite transmitter and receiver manifests itself by a short interference burst in the radio communications link path. However, that effect may be compounded due to the recovery time that applications connected in that path may require, after the radio signal is restored to normal. Some circuits may have several synchronization dependent applications sequentially implemented. For example, a link serving a cable front end could have connected to the terminating digital modem a digital compression expansion device followed by a security identification device. One or two seconds of excessive interference causing the digital modem to lose lock would be followed by failure of the rest of the applications implemented on the link. An immediate restoration of the radio path signal would not necessarily result in immediate restoration of the full service. Each application in the chain generally would require the preceding application to first be restored to normal before it could re-sync itself and correctly operate. A one second interference burst could result in a significant outage time for the full service dependent on that satellite radio link.

While coordination might solve some of the interference problems for some of the large aperture sites, any newly-deployed antennas that exceed the size protected by the epfd limits, however, would be forced to accept any interference received from an NGSO network.[44] This approach is inconsistent with the Commission's basic premise that the rules governing NGSO FSS operations not only will protect existing GSO FSS use of the shared bands but also will "ensure" that NGSO FSS operations "do not unduly constrain future growth of [the GSO FSS service]."[45] Customers have a variety of reasons for electing to use a large-diameter antenna. Among other things, the use of a large-diameter antenna can allow the customer to: locate an earth station outside the satellite's beam center; avoid buying (and paying for) an allocation of extra satellite power; uplink a larger number of circuits; use a smaller (and less expensive) transmitter; or obtain a large rain margin and, thereby, protect communications from outages. PanAmSat, for example, currently serves approximately 100 locations that use antennas with diameters between 9 and 18 meters.

While the proposed approach for dealing with large-diameter antennas may protect existing customers with respect to their existing sites and facilities, this approach would not protect newly-installed large-diameter antennas and, therefore, would limit or foreclose end-users' ability to make the kinds of tradeoffs and decisions described in the previous paragraph.

We note that the NPRM appears not to have addressed the issues of sync loss in any manner. It is also noted that in the international meetings very little consideration was given to the large antennas issue in the Ku bands. Most effort in that area was directed to the Ka bands as a result of U.S. government considerations. PanAmSat recognizes the dilemma posed by the quantity of existing stations and the introduction of new large diameter antenna earth stations as well as the increased sensitivities to interference they may incur with regard to sync loss. It further recognizes the international pressures the Commission has in order to conclude this NPRM in a timely manner. However, because of the far reaching effect that resolution of large antenna issues may have, it may be appropriate to solicit additional comments on the following:

a) Are there any sensitive large aperture earth stations carrying Ku band traffic currently in existence; b) What epfd and apfd limits would be required to protect

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[44] See NPRM AT ¶ 28 (an NGSO system operating in compliance with the final technical rules adopted in this proceeding would be deemed not to be causing "unacceptable" interference to an incumbent user).
[45] NPRM at ¶ 1.

those earth stations; c) What is the probability that new sensitive large aperture earth stations might be implemented and what protection should be required; and, d) What type of traffic and services are dependent on the existing installations and might be carried in the new installations.

E. TT&C (TRANSFER ORBIT AND ON-STATION)/LAUNCH AND ON-ORBIT MALFUNCTIONS

The matter of protection of telemetry, command and ranging (tracking) links has been raised by the Commission in Paragraph 29 of the NPRM, and the suggestion made that the licensees of GSO and NGSO operators should consult with one another during launches. PanAmSat agrees that during launches, GSO satellites (and other satellites as well) face critical, time dependent decisions which must not be impaired with by interfering transmissions from other satellites. However, the nature of TT&C operations requires that these links be protected not only during launches, but also at all other times as well, and that protection would involve very little sacrifice from NGSO systems.

No one would dispute that during launch of GSO satellites, critical operations are under way and interference could be disastrous. This is especially true if such interference caused a wrong command to be received by a new satellite precipitating an inappropriate result, or that an interfered with telemetry reading occurred and caused an improper action to take place, or a ranging operation were to be disturbed so that incorrect information were acted upon by the satellite operator. All of these actions can occur during launch and deployment of GSO satellites and result in major catastrophes for satellite operators.

But this represents only the beginning of the protection TT&C operations demand. TT&C is vital during launch, orbit-raising, deployments, and especially during on-station synchronous orbit operations. Throughout its on-orbit lifetime, a satellite is continuously busy monitoring vital satellite parameters including temperatures, voltages, sun angles, tank pressures, battery health, as well as all the important dynamics of the spacecraft attitude control system. Even a minor error in these readings can cause out-of-limit alarms to be raised and countermeasure actions to take place by the satellite's on-board computers. PanAmSat, like all other GSO operators, requires protection of links with the satellite's health that can be relied upon at all times. There is virtually no time when such links can be routinely interfered with without dire consequences.

At any time during on-orbit operations an unexpected event can occur endangering the satellite's health and continued operation. Fluctuations in telemetry behavior can occur without warning. Important commands can be interfered with whose timing is critical for events such as thruster firings. Satellite anomalies can occur at any time and every fact about the anomaly must be known and transmitted to earth. Missing a critical piece of information, a problem can go unnoticed and can propagate to other systems. One key example occurred recently on a satellite where solar panels strings began shorting out. Dwelling on various sensors allowed engineers the opportunity to understand the problem and act accordingly. If the anomaly had been masked by unknown interferors, the situation could have resulted in a major calamity. With the limited number of sensor points on the satellite it would have been easy to miss these events and the results would have been disastrous. On-orbit TT&C is every bit as vital as TT&C during launch operations.

While GSO spacecraft may differ from another when it comes to TT&C design (different manufacturers have patented ways of doing TT&C), no spacecraft in orbit is immune to co-frequency interference. The prospect of thousands of orbiting NGSO satellites transmitting within the TT&C frequency bands of today's GSO satellites raises major concerns for the continued health of the entire GSO community, both U.S. and foreign. The GSO community simply cannot rely on NGSO promises to monitor EIRP or shutdown when in-line with GSO spacecraft at TT&C frequencies because too much is at stake and too many NGSO satellites are likely to be in orbit when all systems are deployed. The only solution is to segment the TT&C bands from standard frequencies and prohibit NGSO operation on these frequencies.

The amount of bandwidth involved is a small fraction of the total frequency bands the NGSO seek operational authority to use. For example, on PanAmSat's latest satellite, two command frequencies are used, both operating at 13998 MHz. Two telemetry frequencies are also used, these are 12747 and 12748 MHz. Each of these signals has a bandwidth of approximately 1 MHz. Providing a guardband around these frequencies of one megahertz on either side produces a stayout zone of only 3 MHz for the command frequencies and four megahertz for the telemetry frequencies. Since many existing in-orbit satellites operate at C-Band frequencies for their TT&C, the number of stayout bands will be minimal, and these bands will all be located at band edge. Therefore, the Commission should take an inventory of frequencies used for TT&C in the Ku-band and require that NGSO FSS systems not operate on these frequencies.

VI. THE NGSO SERVICE RULES SHOULD REFLECT THESE SYSTEMS' POTENTIAL BURDEN ON GSO OPERATIONS.

PanAmSat is confident that the Commission will endeavor to take into account the needs of GSO systems when it adopts technical rules to govern NGSO operations. Yet PanAmSat also believes that, notwithstanding the Commission's good faith, NGSO systems will have an adverse effect on at least some GSO operations.

The "chilling effect" that the prospect of NGSO systems can have on the GSO industry makes it all the more important that the Commission proceed cautiously in developing NGSO service and licensing rules. PanAmSat, therefore, supports the NPRM's proposal to impose financial qualification, milestone, and reporting requirements and, thereby, minimize the chance that an NGSO licensee will be able to avoid placing its system into operation while, at the same time, maintaining its license.[46] PanAmSat also supports the NPRM's proposal to impose a comprehensive coverage requirement on NGSO systems and to prohibit exclusionary arrangements in foreign countries by NGSO operators in order to ensure that NGSO systems will promote competition and that the burdens imposed on GSO operations will be minimized.[47]

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[46] See NPRM at ¶¶ 85, 87, 88.

[47] See NPRM at ¶¶ 84, 89.

CONCLUSION

Despite the threat posed by NGSO FSS systems to GSO FSS operations, PanAmSat does not oppose the FCC's proposal to permit NGSO systems to operate in spectrum used by the GSO FSS service. However, on behalf of itself and its present and future customers, and in the interests of preserving and promoting the fixed-satellite service's important role in the domestic and global information infrastructures, PanAmSat urges the Commission to adopt and enforce rules for NGSO FSS systems that, in keeping with the technical analysis provided in these Comments, will protect GSO FSS networks from harmful interference, and to treat GSO FSS systems equitably under its fixed-satellite service rules.

Respectfully submitted,

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CERTIFICATION OF PERSON RESPONSIBLE

FOR PREPARING ENGINEERING

INFORMATION SUBMITTED IN THIS APPLICATION

I hereby certify that I am PanAmSat's Chief Scientist and the technically qualified person responsible for preparation of the engineering information contained in this filing. I further certify that I am familiar with Part 25 of the Commission's Rules and that the engineering information submitted in this filing is complete and accurate to the best of my knowledge. I am a registered Professional Engineer in Washington, D.C. and my seal is shown below.

By: ______________________

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Appendix A

INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION STUDY GROUPS

Delayed Contribution
Document 4-9-11/342-E
13 January 1999
Original: English only

Received: 13 January 1999

Subject: Resolution 130 (WRC-97)

United States of America

PROPOSED REVISION TO RESOLUTION 130 PROVISIONAL EPFD AND APFD LIMITS IN THE RESOLUTION 130 14/11GHZ BANDS

The 1997 World Radiocommunication Conference (WRC-97), in order to support the implementation of non-geostationary (NGSO) fixed satellite service (FSS), approved provisional pfd limits to protect GSO FSS networks from interference originating from NGSO FSS networks operating in certain shared bands. WRC-97 Resolution 130, approved at WRC-97, recognized the provisional nature of the approval and designated ITU-R Joint Task Group (JTG) 4-9-11 to review the limits, with the intent of either their final acceptance or modification at the WRC-2000.

Annex 3 and 4 of this document propose candidate 14/11GHz-band epfd and apfd limits. These candidate limits were derived using the criteria described in ITU-R Preliminary Draft New Recommendation 4A/TEMP/66, which proposes a compact method for calculating and verifying permissible levels of interference into GSO networks from NGSO networks sharing the same spectrum.

This document proposes to verify the candidate 14/11GHz-band epfd and apfd limits derived in Annex 3 and 4 by using the 10% criteria as defined in ITU-R 1323 Recommends 3.1 and Equation 2 of this document first described in Doc. 4-9-11/111 and incorporated into 4A/TEMP/66. Using the 10% criteria, the above limits will be tested against the GSO link budgets given in Annex 1 and Annex 2 of Doc. 4-9-11/TEMP/29. These link budgets were provided as a response to CR/92. Additional sensitive links are also considered here to test the proposed limits.

The analysis used to derive the final results in this document included a rigorous testing procedure where the proposed limits are tested against sensitive links. If the proposed limits account for more than 10% of the unavailability for any sensitive link, then the limits failed the verification procedure. The limits were then modified until all the sensitive links pass the test.

This document uses the concept of link availability when applying the 10% criteria. Link availability is defined as the time allowance for which a given BER (or C/N value) requirement is met and is given by

$$Availability = \frac{available\ time}{required\ time} \tag{1}$$

The unavailable time is one minus the available time.

1 Summary & Conclusion: New Proposed epfd and apfd limits

Figure 1-1 shows a flowchart of the procedures used in this analysis. Methodology B′, described in Annex 3 and 4 attached, was used to derive candidate epfd and apfd limits. From Methodology B′, three epfd limit values were calculated. These values include a long term limit (ΔT/T=6% not to be exceeded 99%), a short term limit, and a sync loss limit not to be exceeded at 100% of the time.

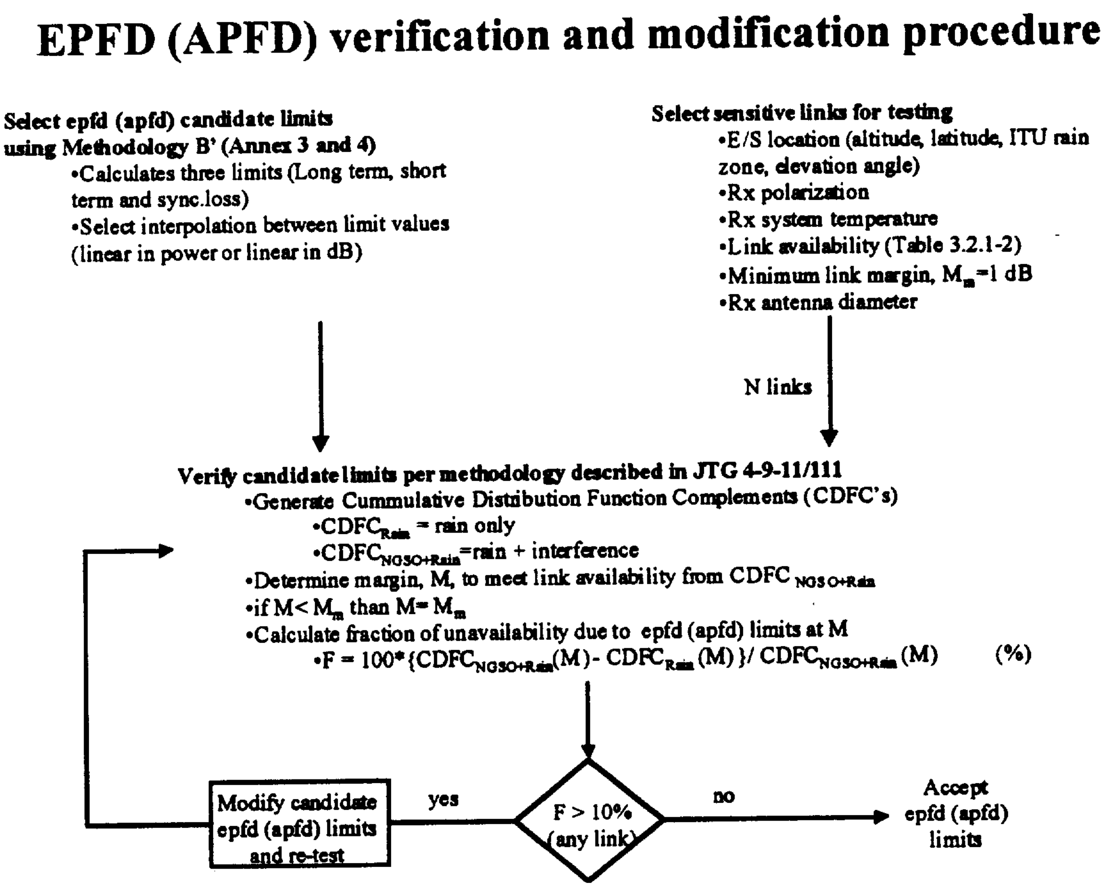


FIGURE 1-1

Flowchart of the epfd (apfd) verification and modification procedure

The 10% criteria (see Section 2.1, following) was next applied to verify and modify the candidate epfd and apfd limits. The 10% criteria assumes the use of, but does not define an interpolation between epfd limit values.

Because GSO networks are globally distributed, an extended database of link scenarios was considered in this analysis. Accordingly, link budgets in Annex 1 and 2 of Doc.4-9-11/TEMP/29 and also newly considered globally pervasive links developed for this analysis were used in the evaluation process. The aggregate epfd and apfd limits required to protect the most sensitive of this globally distributed GSO FSS link database are shown in Tables 1-1 and 1-2.

This extended data base was developed because it was felt that the link budgets in Doc. 4-9-11/TEMP/29 were not fully representative of all geographic locations or the distribution of earth stations in each rain zone. Sensitive links were identified for each geographic area so that the entire possible GSO FSS infrastructure was represented when developing protection limits. As expected, the results indicate that the sensitive links are located in the driest rain zone, with the highest altitude and elevation angle.

A large number (>2700) of urban centers were examined in order to identify the sensitive links. It was determined that there are a significant number of cities with large populations distributed within dry rain zones (Figures 3.2.2-1 and 3.2.2-2). Population and number of urban centers in each rain zone are considered to be an indication of the number of earth stations that might exist in each location. Earth station elevation angles were calculated assuming the earth station and satellite were at the same longitude.

It is understood that the GSO FSS consists of a wide variety of links. Further, the links are constantly changing and evolving. The 4-9-11/TEMP/29 links do not take this into account for determining a complete understanding of what constitutes a sensitive link in the presence of NGSO interference and the 10% criteria as determined in Equation 2 (see section 2.1). A parametric study was performed as part of this analysis to ensure that the global GSO service and not just a limited set of GSO link designs are protected.

The sensitive links and the JTG 4-9-11/TEMP/29 links were assumed to operate with a minimum availability determined by the earth station antenna size. For this study it was assumed that the links had just enough margin to provide that minimum availability, unless the margin was less than 1 dB. The minimum system margin for any link was assumed to be 1 dB.

The 10% criteria requirement in section 2.1 (Equation 2) is harder to meet for lower link availabilities (See Figures 5-2 to 5-5). Minimum reasonable link availabilities were assumed for each earth station antenna size (Table 5-1). In calculating the apfd limits no power control was assumed and a link availability of 99.99% was arbitrarily chosen. Less link margin is required to operate at the lower availabilities. Higher availabilities in the links from Doc. 4-9-11/TEMP/29 don't preclude the existence (current or future) of links with lower availabilities.

Since power is a limited resource on a satellite, earth stations are assumed to operate with minimum margins to maximize the satellite capacity. Thus link margins were assumed to be just sufficient to meet the availability requirement given rain and NGSO interference. This is a common practice wherein

GSO operators minimize margins so as to maximize satellite usage. Document [USJTG 4-9-11/53] provides a clear explanation of this principle.

In very low intensity rain regions this assumption of minimal margin may be considered to be unduly pessimistic. Accordingly, a minimum system margin of 1 dB was assumed for all the links regardless of the link availability requirement.

The sensitive links used the system temperatures shown in Table 3.2.1-2. These temperatures include a 20% allowance for interference from other GSO's.

Using the 10% criteria, the candidate epfd and apfd limits were verified and when necessary modified. For each link the link margin (M) that gives the desired GSO FSS network availability with rain and NGSO interference present is determined. If M is less than the 1 dB minimum margin it is set equal to 1 dB. Then with only rain fading modeled the link availability (unavailability) at the link margin M is determined. The fraction of the unavailability due to NGSO interference is calculated using Equation 2. If this fraction exceeds the 10% criteria the link fails. If any link fails the Equation 2 test, then the epfd (apfd) limits are modified until all links pass.

Table 1-1 to 1-2 presents epfd and apfd limits needed to protect all of the links considered in the study for the 14/11GHz bands identified in Resolution 130. The limits chosen will adequately protect a significant majority of the GSO networks from NGSO networks sharing the same spectrum and will therefore serve as the selected bounds.

TABLE 1-1

Proposed Aggregate 14/11GHz-band epfd Limits

	Provisional Single Entry EPFD Limits (WRC-97)		Proposed Aggregate NGSO system EPFD limits	
Antenna Diameter (m)	EPFD ($dBW/m^2/4K$ Hz)	Percent of time not to exceed (%)	EPFD ($dBW/m^2/4K$ Hz)	Percent of time not to exceed (%)
0.6	-179	99.7	-183	99
0.6	-170	99.999	-173	99.97
0.6	-170	100	-172	100
1.2			-189	99
1.2			-178	99.98
1.2			-177	100
1.8			-192	99
1.8			-181	99.99
1.8			-180	100
3	-192	99.9	-197	99
3	-186	99.97		
3	-173	99.999	-185	99.995
3	-170	100	-184	100
7			-203	99
7			-191	99.999
7			-190	100
10	-195	99.97	-206	99
10	-178	99.999	-194	99.999
10	-170	100	-193	100

TABLE 1-2

Proposed Aggregate 14/11GHz-band apfd Limits

Satellite Receive Antenna	Provisional Single Entry APFD Limits (WRC-97)		Modified Aggregate NGSO system apfd limits	
Beamwidth (degrees)	APFD (dBW/m^2/4KHz)	Percent of time not to exceed (%)	APFD (dBW/m^2/4 KHz)	Percent of time not to exceed (%)
1	-170	100	-186	100
2			-181	100
3			-177	100

1.1 Generic Parameters Considered for all Links

In order for there to be agreement on new epfd and apfd limits there has to be agreement or consensus on the parameters input to the 10% criteria described in Section 2.1 below. These parameters can be discussed in terms of link budgets or through other arguments. The parameters are:

1. Earth station height
2. Earth station latitude
3. Rain Zone
4. Earth station elevation angle
5. Receive antenna polarization (Circular, Vertical, or Horizontal)
6. Receive system temperature
7. Link availability
8. Minimum link margin
9. Receive antenna diameter
10. Frequency

2 Methodologies

2.1. Description of the 10% Criteria

According to Recommends 3 of ITU-R S.1323, NGSO interference can be responsible for at most 10% of the time allowance for the given BERs (or C/N values) as specified in the short-term performance objectives of the desired GSO FSS network. The 10% criteria is used to test that the epfd meets this short term requirement. In this methodology the GSO FSS link unavailability is calculated (for a range of link degradation, M) both with and without NGSO interference. The NGSO interference is acceptable if it meets the criteria shown below.

$$\frac{(1-CDF(M)_{NGSO+Rain})-(1-CDF(M)_{Rain})}{(1-CDF(M)_{NGSO+Rain})} \leq 10\% \qquad (2)$$

where:

CDF = Cumulative distribution function,

$CDF(M)_{Rain}$ = The probability that rain fade causes a link degradation less than M.

$CDF(M)_{NGSO+Rain}$ = The probability that the degradation from rain and NGSO interference causes a link degradation less than M.

The $CDF(M)_{Rain}$ is calculated using either the Crane or ITU rain model. The $CDF(M)_{NGSO+Rain}$ is determined by convolving the NGSO interference probability density function (pdf) with the rain pdf to form the density function representing total link degradation. This methodology assumes that rain fade and interference occur independently from one another. For downlinks the NGSO interference pdf is formed from epfd limits and convolved with the downlink rain pdf calculated from the Crane or ITU model. On the uplink the apfd limits are used to form the interference pdf and it is convolved with the uplink rain pdf. The model does not try to combine the effects of uplink and downlink rain attenuation.

The 10% criteria requires input parameters shown below.

1. Earth station height
2. Earth station latitude
3. Rain Zone
4. Earth station elevation angle
5. Receive antenna polarization (Circular, Vertical, or Horizontal)
6. Receive system temperature
7. Link availability
8. Minimum link margin
9. Receive antenna diameter
10. Frequency

11. apfd or epfd limits

TABLE 2.1-1

Example of Limits

Percentage time limit not exceeded (%)	**Limit value ($dBW/m^2/BW$)**
99.7	-179
99.999	-170
100	-170

In the calculation of the apfd limits, the receiver is on the satellite and the earth station is the transmitter. In the calculation of the epfd limits the receiver is at the earth station. The system temperature is a total system temperature and includes all noise and interference contributions in the link budget.

The formulation of the convolution assumes that when interference and rain occur at the same time the interfering signal is faded the same amount as the desired signal, as shown in the derivation below.

Equation 3 below represents the downlink carrier to noise power ratio when there is rain fading and interference.

$$\frac{C}{N_{downlink}} = \frac{Ca}{(Ts+Tr)?KB + I\ ?b} = \frac{C}{\frac{1}{a}?(Ts+Tr)+I\frac{b}{a}} \qquad (3)$$

where:

a = rain attenuation on desired link,

b = rain attenuation on undesired link,

Ts = total receive system noise temperature,

Tr = rain noise temperature,

K=Boltzman's constant,

B=bandwidth,

C = desired signal power,

I = interfering power.

The degradation due to interference and rain (Z) is the ratio of system temperature with interference and rain (denominator in Equation 3) and the system temperature without rain or interference. The resulting degradation is shown below:

$$Z = \frac{\frac{KB}{a}\left(Ts + Tr\right) + I\frac{b}{a}}{KBTs} = \frac{1}{a}\left(1 + \frac{Tr}{Ts}\right) + \frac{I}{KBTs}\frac{b}{a} \qquad (4)$$

This degradation can be separated into a component due to rain and a component due to interference as shown below:

$$X = \frac{1}{a}\left(1 + \frac{Tr}{Ts}\right) \qquad (5)$$

$$Y = \frac{I\frac{b}{a}}{KBTs} \qquad (6)$$

where X is the degradation caused by rain and Y is the term due to interference. The analysis assumes that X and Y are independent and therefore their pdf's can be convolved. Additionally, the 10% criteria assumes the fading on the undesired link (b) is the same as the fading on the desired link (a). Thus the ratio b/a = 1 and the unfaded interference density function can be used when convolving X and Y.

The program developed to implement the convolution for this analysis, was verified against the results of an alternate simulation methodology. This simulation methodology is similar to the methodology in ITU-R JTG 4-9-11/169. One advantage of the convolution, used in this analysis, is that it takes seconds to complete several hundred runs using an FFT implementation.

2.2 Methodology in Document 4-9-11/169

The methodology in document JTG 4-9-11/169 differs from the convolution procedure in document 4-9-11/111. The program implements a link budget for calculating the received margin when there is rain attenuation and NGSO interference. In the case of a repeater satellite the link budget includes both up- and down-link parameters.

The program forms the joint density of the uplink and downlink rain attenuation and NGSO interference assuming that these effects are independent. The program integrates this joint density over all degradations where the link margin is less than zero and thus determines the probability of the link being degraded. As with the convolution methodology in Doc. 4-9-11/111 the program calculates the probability of the link being degraded with and without the NGSO interference.

One consequence of the formulation in document Doc. 4-9-11/169 may be an apparent slight increase in the link availability. Normally, link availability is calculated assuming that the uplink unavailability and downlink unavailability do not occur at the same time. Thus in practice the system availability is calculated as the product of the uplink and downlink availabilities. Integrating over the joint density of the uplink and downlink rain attenuation will result in a higher availability than taking the product of the uplink and downlink availabilities.

As argued in the last section, for the sensitive links, the contribution of the uplink to the downlink should be negligible. Therefore, results from using the methodology in document 4-9-11/169 should agree with the results from using the methodology in document 4-911/111. If there are differences they should become apparent by looking at the program inputs. System temperature and the transmission gains can be determined from the link budgets as described above.

3 Links

3.1 4-9-11/TEMP/29 Annex 1 and Annex 2 Links

Circular letter CR/92 was sent out by the JTG requesting link budget information on GSO FSS sensitive links. Annex 1 and 2 of 4-9-11/TEMP29 include the link budget parameters sent to the JTG by various administrations. The Annex 1 link information includes only the minimum information required to perform the convolution calculation while Annex 2 includes complete link budget information. The approach used in this paper is to apply the convolution methodology to test the candidate epfd and apfd limits against the GSO FSS links in the Annexes. In this report the analysis was limited to transparent 14/11GHz-band satellites.

For this analysis, it was decided to not consider the link margins and availabilities provided in the link budgets. These availabilities represent specific situations and not the general situations that could exist. Since excess margin represents an unnecessary economic burden, most commercial links are designed with little or no excess.

For this analysis the calculation of satellite (uplink) and earth station temperatures are derived from the following formulas:

$$T_{sat} = \frac{10^{\left(C_u - \left(\frac{C}{IM}\right)_u\right)} + 10^{\left(C_u - \left(\frac{C}{TxXpol}\right)_u\right)} + 10^{N_u} + 10^{\left(C_u - \left(\frac{C}{RxXpol}\right)_u\right)} + 10^{\left(C_u - \left(\frac{C}{ASI}\right)_u\right)} + 10^{\left(C_u - \left(\frac{C}{FS}\right)_u\right)} + 10^{\left(C_u - \left(\frac{C}{FR}\right)_u\right)}}{K ? B} \tag{7}$$

$$T_{ES} = \frac{10^{\left(C_d - \left(\frac{C}{IM}\right)_d\right)} + 10^{\left(C_d - \left(\frac{C}{TxXpol}\right)_d\right)} + 10^{N_d} + 10^{\left(C_d - \left(\frac{C}{RxXpol}\right)_d\right)} + 10^{\left(C_d - \left(\frac{C}{ASI}\right)_d\right)} + 10^{\left(C_d - \left(\frac{C}{FS}\right)_d\right)} + 10^{\left(C_d - \left(\frac{C}{FR}\right)_d\right)} + 10^{\left(C_d - \left(\frac{C}{AdjTr}\right)_d\right)}}{K ? B} \tag{8}$$

where

C_u = the power received at the satellite (dB)

$(C/IM)_u$ = transmit carrier-to-intermodulation product ratio (dB) on the uplink

$(C/TxXpol)_u$ = transmit carrier-to-transmit cross polarization isolation ratio (dB) on the uplink

N_u = uplink thermal noise (dB)

$(C/RxXpol)_u$ = carrier-to-receiver cross polarization isolation ratio (dB) on the uplink

$(C/ASI)_u$ = carrier-to-adjacent satellite interference ratio (dB) on the uplink

$(C/FS)_u$ = carrier-to-fixed service interference ratio (dB) on the uplink

$(C/FR)_u$ = carrier-to- frequency reuse isolation (dB) on the uplink

C_d = The power received at the earth station (dB)

$(C/IM)_d$ = transmit carrier-to-intermodulation product ratio (dB) on the downlink

$(C/TxXpol)_d$ = transmit carrier-to-transmit cross polarization isolation ratio (dB) on the downlink

N_d = downlink thermal noise (dB)

$(C/RxXpol)_d$ = carrier-to-receiver cross polarization isolation ratio (dB) on the downlink

$(C/ASI)_d$ = carrier-to-adjacent satellite interference ratio (dB) on the downlink

$(C/FS)_d$ = carrier-to-fixed service interference ratio (dB) on the downlink

$(C/FR)_d$ = carrier-to- frequency reuse isolation (dB) on the downlink

$(C/AdjTr)_d$ = carrier-to-adjacent transponder isolation (dB) on the downlink

K = Boltzman's constant (numerical)

B = Carrier bandwidth (Hz)

In equations 7 and 8, the adjacent satellite and fixed service interference is assumed to be unfaded by rain. This is a worst case assumption that over estimates the received system temperature.

For transparent satellites the total system temperature (T_{sys}) at the receive earth station including the contribution of the uplink is given by

$$T_{sys} = T_{E/S} + \gamma ?T_{sat} \tag{9}$$

where γ is the transmission gain and is equal to the numerical ratio Cu/Cd.

The satellite temperature (T_{sat}) is used when testing the apfd limits and the total system temperature (T_{sys}) is used when testing the epfd limits.

Figures 3.1-1 to 3.1-3 show a distribution of T_{sat}, T_{sys} and γ derived from the link budget information in Annex 1 and Annex 2 of 4-9-11/TEMP/29. The full link budget information can be looked up based on the carrier ID's. Carrier ID's 1 to 219 are from Annex 2 and carrier ID's 220 to 248 are from Annex 1 of 4-9-11/TEMP/29. Carrier ID's 54 to 219 were missing Earth station elevation angles and receive earth station rain zones. To complete the analysis the missing elevation angles were arbitrarily set to 20 degrees and the missing rain zones were set to ITU rain zone E.

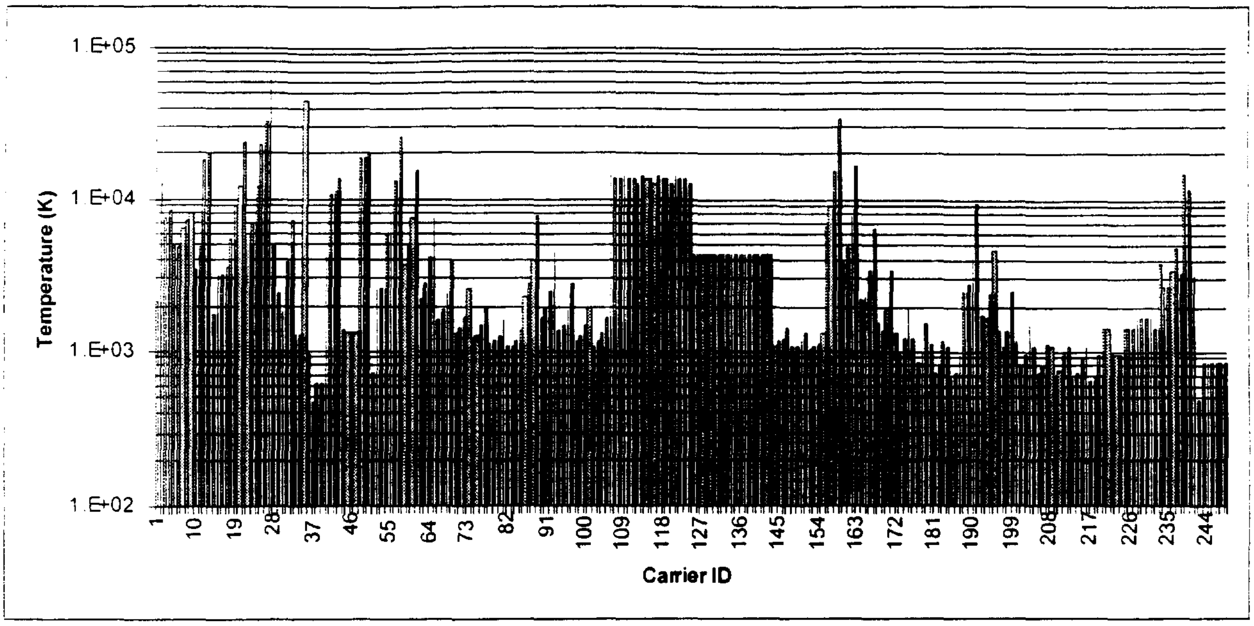


FIGURE 3.1-1

14/11GHz-band Transparent Satellite Total Uplink Noise Temperatures

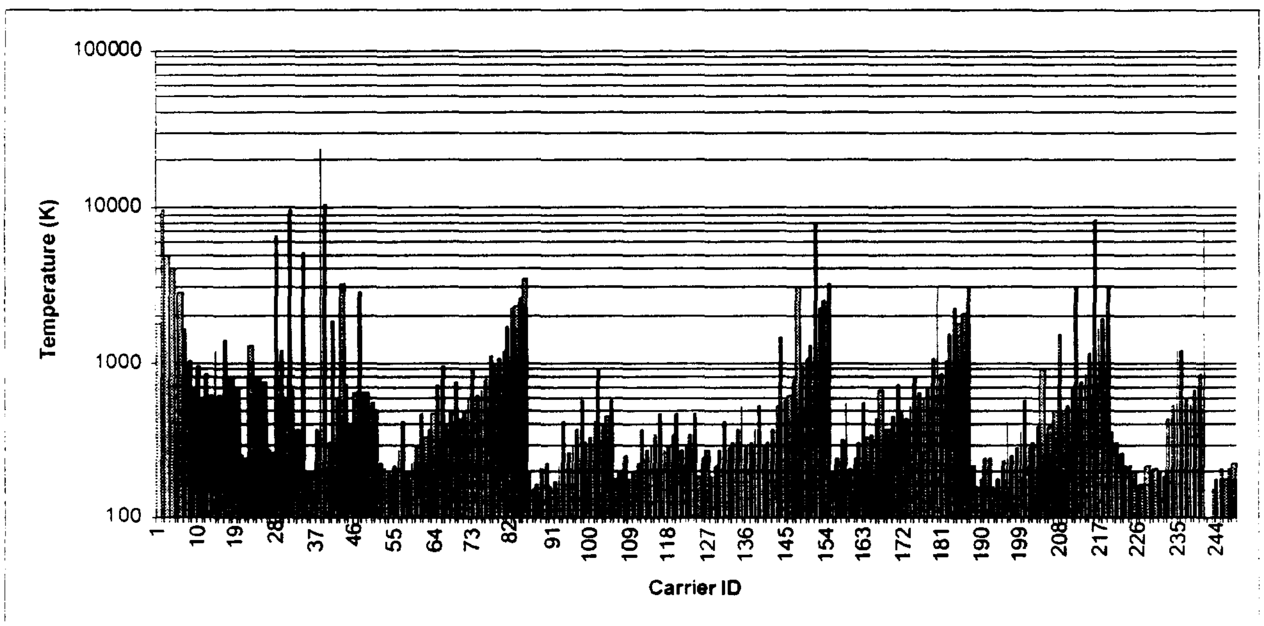


FIGURE 3.1-2

14/11GHz-Band Transparent Satellite Total Downlink System Temperatures

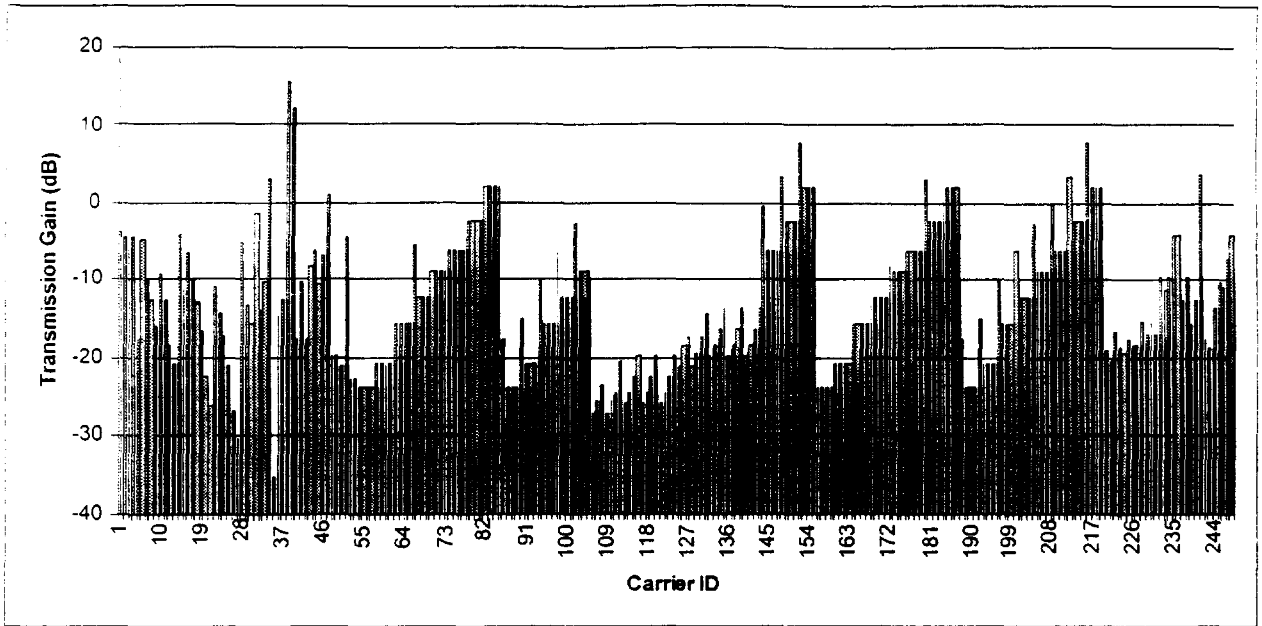


FIGURE 3.1-3

14/11GHz-band Transparent Satellite Transmission Gains

Notice that most of the transmission gains in Figure 3.1-3 are negative dB values. Thus the contribution T_{sat} to T_{sys} is reduced by γ. From Figure 3.1-2 and Figure 3.1-3 it can be seen that in general the links with the smallest γ have the smallest T_{sys}. The links with the smallest T_{sys} are the links most sensitive to NGSO interference. For the most sensitive links, those with the smallest T_{sys}, the uplink noise contribution is negligible. Additionally, most of these systems implement power control to overcome the uplink rain fades. Thus there should be no loss in accuracy, in the methodology used here, to analyze the downlink separately from the uplink.

3.2 Sensitive Link Budgets

The epfd and apfd limits need to protect sensitive links. Sensitive links are those that have minimum system temperatures and minimum rain margins. The rain margin is determined by the earth station location in terms of rain zone, altitude and elevation angle.

3.2.1 Denver Link Budget

Epfd and apfd levels given in Annex 3 and 4 of this document were derived for the most sensitive link located in Denver. The characteristics of this link are defined in Table 3.2.1-1.

TABLE 3.2.1-1

Denver (USA) link characteristics

Earth Station Altitude	1.61 km
Earth Station Latitude	39.73° N
Elevation Angle	43.2°
Polarization	Circular
Rain Model	ITU-R 618-5
ITU Rain Region	E
Satellite Location	101° W

This link was assumed to have minimum system temperature. The system temperatures that were used were increased 20% to account for interference from other GSO satellite systems. Table 3.2.1-2 shows the system temperatures used in the analyses.

TABLE 3.2.1-2

Minimum System Temperatures Used in Annexes 3 and 4 with a 20% allowance for GSO interference included

apfd calculation	625 K
epfd calculation	188 K

3.2.2 Locations Around the World

This analysis assumes that satellite links are, in most instances, located to serve urban populations. Accordingly it is reasonable to assume that those satellite links serving urban areas located in dry climates and at higher elevations would be the most sensitive. In order to identify where sensitive links might exist throughout the world, an international data base of urban population areas located by latitude, longitude, ITU rain zone and average altitude was created. The urban population information used to create the file was derived from data provided by the Population Division, Department of Economic and Social Affairs of the United Nations. ITU software program "Rainzone.exe" was used to identify the rain zone of each urban population center. Average altitude information was taken from topographical data available from the United States National Oceanic and Atmospheric Administration.

The resulting file provides population, location, rain zone and altitude information for over 2700 urban population centers. The minimum population for classification as an urban center was limited to 75,000 people (except for some few smaller island locations). The total population of the urban areas represented in the file represents about forty percent of the total world population. Annex 1 is an extract of the database showing information for the three driest ITU rain zones (a, b and c). Figure 3.2.2-1 graphically summarizes the total of urban center populations contained in each ITU rain zone, and Figure 3.2.2-2 graphically illustrates the number of urban areas within each ITU rain zone. For reference, Figure 3.2.2-3 shows a map of the ITU world rain zones. The Figures and the Annex demonstrates that there are a significant number of cities with large populations distributed within these dry rain zones. It has to be presumed that these urban areas will have satellite communication requirements similar to those of the rest of the world.

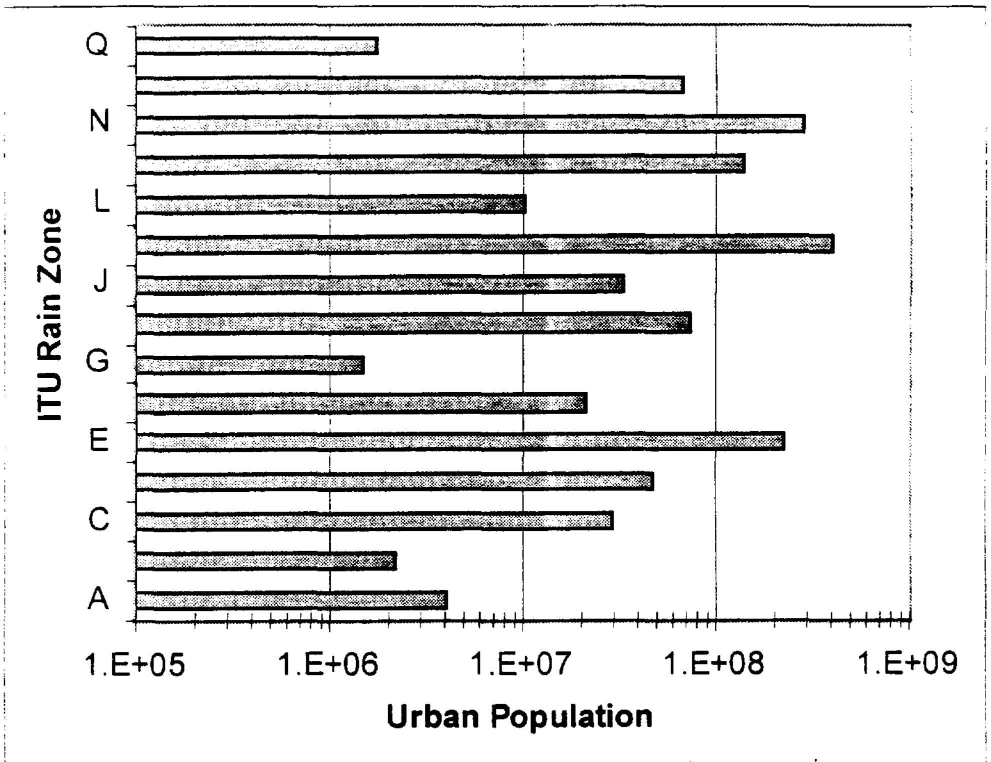


FIGURE 3.2.2-1

Urban Population within ITU Rain Zones

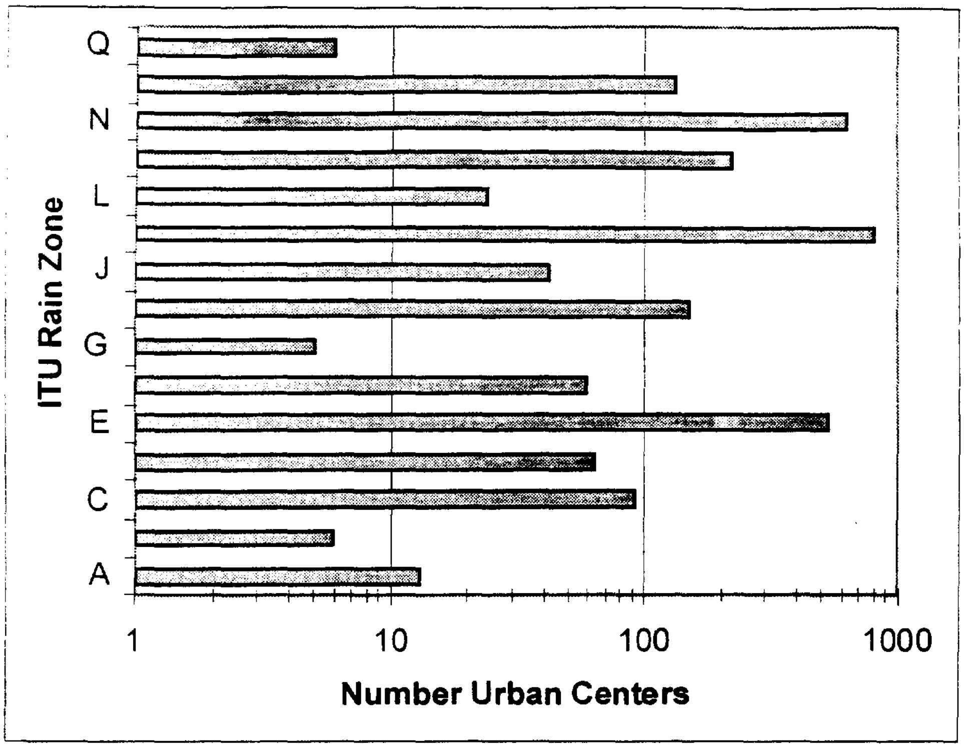


FIGURE 3.2.2-2

Number of Urban Centers per ITU Rain Zone

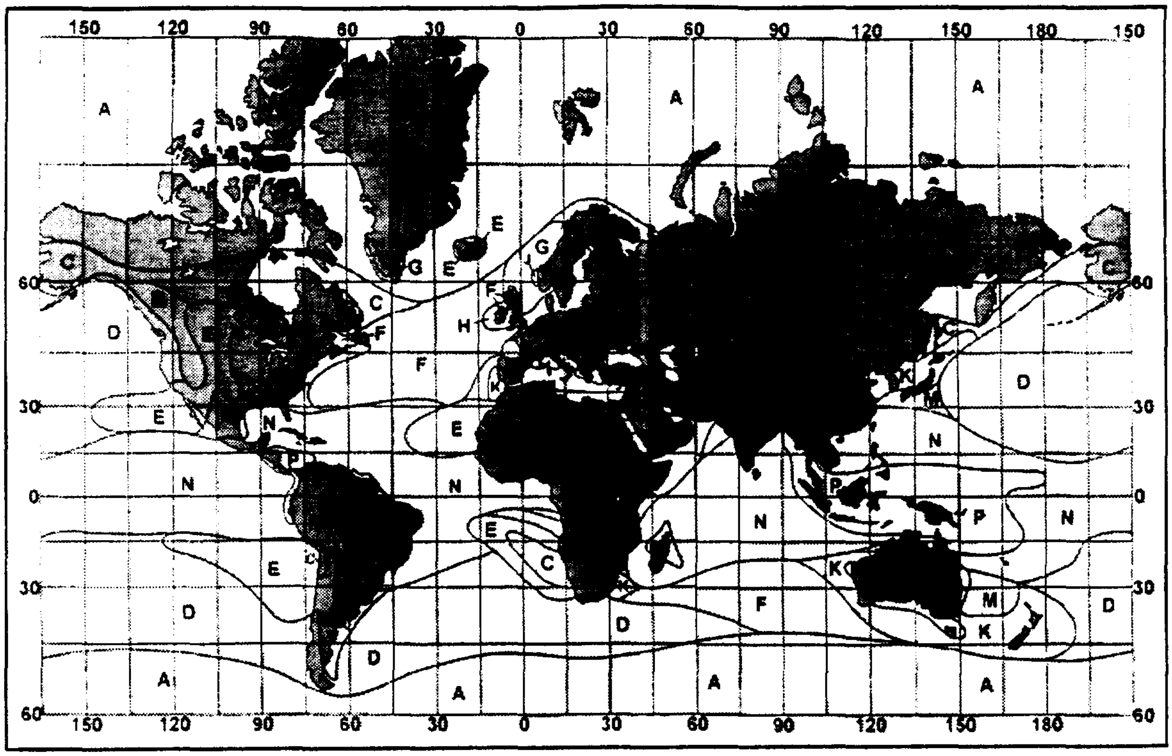


FIGURE 3.2.2-3

ITU World Rain Zones

4 Methodology for Determining the Candidate epfd and apfd Limits

The calculation of the candidate epfd and apfd limits is discussed in detail in Annex 3 and 4. The methodology uses a ΔT/T approach for calculating interference (see 4A/TEMP/66).

The calculated values for epfd and apfd limits from Annex 3 and 4 are based on the specific system parameters, representing a sensitive link, that are presented in Tables 3.2.1-1 and 3.2.1-2. The long term interference is assumed to be at 99% availability with a ΔT/T of 6%. A short term limit is calculated using Recommendation ITU-R S.1323 Methodology B. A synchronization limit, 2 dB tighter than the short term limit was also calculated (see reference 4B/TEMP/30). This limit cannot be exceeded 100% of the time.

Tables 4-1 and 4-2, show the aggregate NGSO system epfd and apfd limits proposed in Annex 3 and 4, respectively.

TABLE 4-1

Method B′ 14/11GHz-band candidate epfd Limits

	Aggregate NGSO system epfd limits	
Antenna Diameter (m)	epfd (dBW/m^2/4K Hz)	Percent of time not to exceed (%)
0.6	-176	99
0.6	-169	99.97
0.6	-163	100
1.2	-181	99
1.2	-174	99.98
1.2	-168	100
1.8	-185	99
1.8	-176	99.99
1.8	-171	100
3	-189	99
3	-176	99.995
3	-173	100
7	-197	99
7	-181	99.999
7	-180	100
10	-200	99
10	-185	99.999
10	-183	100

TABLE 4-2

Method B′ 14/11GHz-band candidate apfd Limits

Satellite Receive Antenna	Aggregate NGSO system apfd limits	
Beamwidth (degrees)	APFD ($dBW/m^2/4$ kHz)	Percent of time not to exceed (%)
1	-176	100
2	-171	100
3	-167	100

5 Results

In this report candidate epfd and apfd limits were tested and modified to meet the 10% criteria in 1323 for selected GSO FSS links. Candidate epfd and apfd limits are developed in Annex 3 and 4, respectively. The apfd limits were selected so that the uplink interference does not exceed 6% of the system temperature for 100% of the time.

Three candidate epfd limit values were calculated. These values include a long term limit (1% unavailability), a short term limit (corresponding to the operating link availability), and a (sync loss) limit, not to be exceeded at 100% of the time. The convolution methodology used to test and modify the epfd limits assumes an interpolation between the epfd limit values. In this analysis the three epfd limits were first converted to degradation. Additional points were then interpolated between the three degradation points as shown in Figure 5-1.

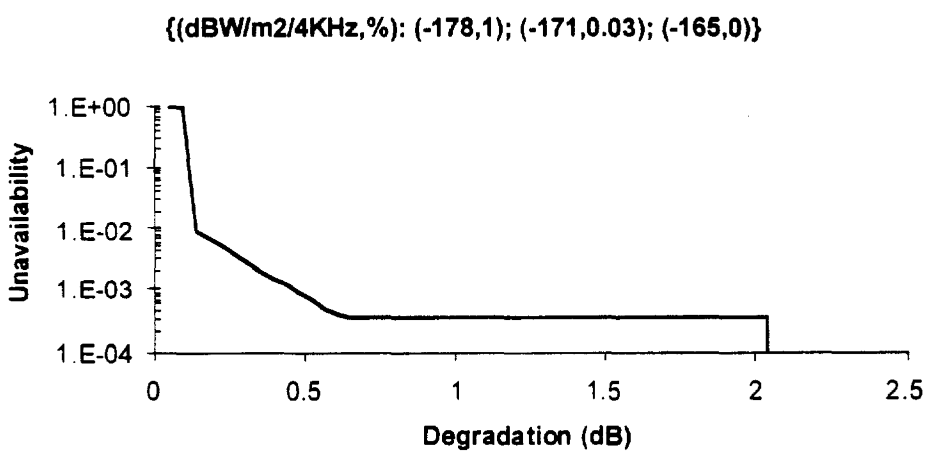


FIGURE 5-1

Cumulative Distribution Function Complement from EPFD limits

Figures 5-2 and 5-3 show example outputs using the convolution methodology. The figures show the Cumulative Distribution Function Complements (CDFC) for rain alone, and for rain plus NGSO interference (epfd limits). Additionally, the figures show the fraction of unavailability due to the NGSO interference (epfd limits) calculated using Equation 2.

In general, the figures show that it is more difficult to meet the 10% criteria for the larger unavailability times. In evaluating the links, a minimum link availability was therefore assumed. Table 5-1 shows the minimum availabilites assumed when generating epfd limits as a function of antenna size.

TABLE 5-1

Availabilities Assumed when Generating epfd Limits

Antenna size (m)	**Unavailability (%)**	**Availability (%)**
0.6	0.3 %	99.7 %
1.2	0.2%	99.8%
1.8	0.1%	99.9
3	0.05%	99.95
7	0.01%	99.99%
10	0.01%	99.99%

For determining apfd limits, an availability of 99.99% (0.01% unavailability) was always assumed.

From Table 5-1 the unavailability assumed for a 0.6 m antenna was 0.003. The fraction of the unavailability due to NGSO exceeds 20% in Figure 5-2 at the 0.003 unavailability point on the rain plus NGSO curve. Thus this link failed the 10% requirement for the given epfd limits.

From the figures you can also determine how much margin (degradation) is required to meet the 10 % criteria. In Figure 5-2, the link needs a margin of approximately 2.4 dB to reduce the fraction of unavailability due to the NGSO below 10%.

Figures 5-2 and 5-3 were calculated using the interpolation shown in Figure 5-1. Notice that the discontinuity in the epfd limits produces a sharp dip in the rain plus NGSO CDFC. Figure 5-2 and 5-3 was calculated for system temperatures (Ts) equal to 188 K and 564 K, respectively. Notice that an increase in system temperature results in less margin needed to pass the 10% criteria. In Figure 5-2 with Ts=188 K the link requires a margin of about 2.4 dB while in Figure 5-3, with Ts=564 K, the link requires a margin of about 1.1 dB.

Figure 5-2: Evaluation of EPFD limits (interpol. in dB) for an E/S located in Denver (0.6 m antenna, Ts=188 K)

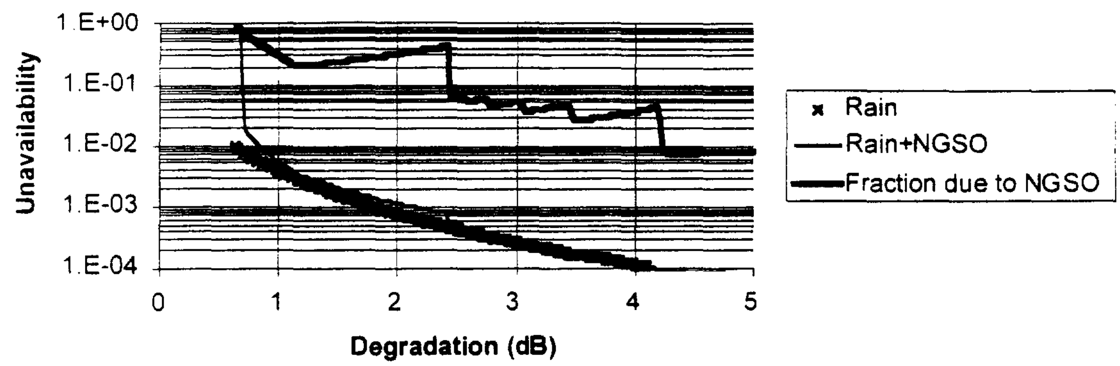
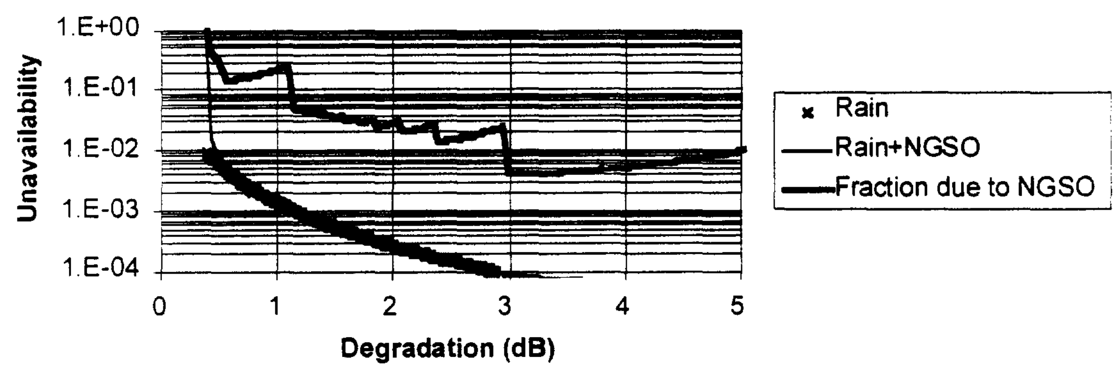


Figure 5-3: Evaluation of EPFD limits (interpol. in dB) for an E/S located in Denver (0.6 m antenna, Ts=564 K)



5.1 Doc. 4-9-11/TEMP/29 Annex 1 and Annex 2 Links

In this section the links from Doc. 4-9-11/29, Annex 1 and Annex 2 are analyzed. For the Annex 2 links, the system temperatures were calculated using Equations 7, 8 and 9 and minimum availabilities in Table 5-1 were selected for each receive antenna size. The justification for setting margins to just meet the link availability is given in Doc. 4-9-11/53.

The initial limits derived in Annex 1 and Annex 2 were tested. If links failed the 10% criteria, then the limits were increased 1 dB and tested again. Testing stopped when all links passed. The tables below show only those carrier Id's that failed the 10% criteria in Equation 2. Epfd (apfd) limits are considered acceptable when all carriers meet the 10% interference limit per ITU-R 1323 (Rec. 3). The limit values resulting in all carrier Id's passing are in bold in the tables. Only the limit values were varied. The epfd (apfd) percentages were kept constant.

5.1.1 Epfd results

There were 248 carrier id's (links) analyzed in this section. The distribution of receive earth station antenna sizes are shown in Table 5.1.1-1. For each antenna size there is only a limited set of links tested.

TABLE 5.1.1-1

Distribution of receive earth station antenna sizes

Antenna size, A (m)	Number of carriers
A ≤ 0.6	55
0.6< A ≤ 1.2	48
1.2< A ≤ 1.8	31
1.8< A ≤ 3.0	45
3.0 < A ≤ 7.0	40
A >7.0	29

Table 5.1.1-2 shows the results for the 0.6 m antenna. The top of the table shows the epfd values being tested. The rest of the table shows the fraction of the unavailability due to NGSO interference for those carriers that exceeded the 10% criteria.

The first column shows the results for the initial epfd limits selected (-176,-169, -163 dBw/m^2/4KHz). For example, carrier ID 242 failed at this epfd limit because the unavailability due to the NGSO interference is 16.8 %. Of the 248 links, 31 failed to meet the 10% criteria. In order for all the carriers to pass the 10% criteria, the epfd limits need to be more stringent by 6 dB.

TABLE 5.1.1-2

14/11GHz-band epfd limits for 0.6 m antenna (1 dB minimum margin)

% time EPFD cannot be exceeded	EPFD (dBW/m²/4KHz)						
99	*-176*	-177	-178	-179	-180	-181	**-182**
99.97	*-169*	-170	-171	-172	-173	-174	**-175**
100	*-163*	-164	-165	-166	-167	-168	**-169**
Carrier Id	**Fraction of unavailability due to NGSO**						
242	0.168	0.167	0.167	0.106	0.106		
15	0.365						
58	0.102	0.102	0.101				
59	0.101	0.101	0.101				
60	0.102	0.102					
61	0.105						
90	0.101	0.101	0.101				
91	0.112	0.112	0.111				
92	0.104	0.103	0.103				
93	0.106	0.106	0.106				
109	0.112	0.111	0.111				
110	0.112	0.112	0.101				
111	0.101	0.101					
112	0.102	0.102					
128	0.108	0.108	0.107				
129	0.107	0.106	0.106				
130	0.109	0.109					
131	0.101						
160	0.111	0.111					
161	0.109	0.109					
162	0.106	0.106					
163	0.103						
192	0.109	0.109					
193	0.111	0.110	0.110				
194	0.113	0.113	0.112				
195	0.110	0.110					
220	0.172	0.171	0.171	0.105	0.105		
221	0.170	0.169	0.168	0.168	0.102		
222	0.227	0.168	0.167	0.167	0.101	0.101	
223	0.227	0.170	0.170	0.169	0.107	0.107	
224	0.225	0.167	0.166	0.166	0.101	0.101	

Tables 5.1.1-3 to 5.1.1-5 show results for antenna sizes 1.2, 1.8, and 3 meters, respectively. In general the epfd limits for these antenna sizes need to be tightened more than 4 dB relative to the levels proposed in Annex 3.

TABLE 5.1.1-3

14/11GHz-band epfd limits for 1.2 m antenna (1 dB minimum margin)

% time EPFD cannot be exceeded	EPFD (dBW/m^2/4KHz)							
99	*-176*	-177	-178	-179	-180	-181	-182	**-183**
99.97	*-169*	-170	-171	-172	-173	-174	-175	**-176**
100	*-163*	-164	-165	-166	-167	-168	-169	**-170**
Carrier Id	**Fraction of unavailability due to NGSO**							
225	0.157	0.156	0.156					
237	0.101							
228	0.204	0.156	0.155	0.155				
229	0.205	0.157	0.156	0.156				
233	0.159	0.159						
21	0.377	0.278	0.241	0.240	0.203	0.165	0.165	
27	0.340	0.280	0.244	0.208	0.207	0.171	0.171	
35	0.215	0.163	0.162	0.162	0.105			
62	0.101							
63	0.101							
64	0.103							
94	0.101							
95	0.106							
96	0.109							
97	0.101							
113	0.105							
114	0.108							
115	0.105							
132	0.102	0.102						
133	0.104	0.103						
134	0.110							
164	0.101							
165	0.105							
197	0.109	0.109						
198	0.102	0.102						
199	0.102							
226	0.248	0.204	0.204	0.157	0.156	0.156		
227	0.248	0.204	0.203	0.155	0.155	0.155		
230	0.250	0.205	0.157	0.157	0.156	0.104		
231	0.250	0.206	0.206	0.158	0.158			
234	0.159	0.158	0.158					
238	0.159	0.158	0.158					
240	0.159	0.102						
243	0.248	0.204	0.204	0.156	0.156	0.156		

TABLE 5.1.1-4

14/11GHz-band epfd limits for 1.8 m antenna (1 dB minimum margin)

% time EPFD cannot be exceeded	EPFD (dBW/m^2/4KHz)						
99	*-185*	-186	-187	-188	-189	-190	-191
99.99	*-176*	-177	-178	-179	-180	-181	-182
100	*-171*	-172	-173	-174	-175	-176	-177
Carrier Id	**Fraction of unavailability due to NGSO**						
20	0.283	0.238	0.207	0.176	0.175	0.140	
26	0.278	0.238	0.207	0.174	0.173	0.138	
30	0.180	0.143					
244	0.177	0.176	0.140	0.140			

TABLE 5.1.1-5

14/11GHz-band epfd limits for 3 m antenna (1 dB minimum margin)

% time EPFD cannot be exceeded	EPFD (dBW/m^2/4KHz)				
99	-189	-190	-191	-192	-193
99.995	-176	-177	-178	-179	-180
100	-173	-174	-175	-176	-177
Carrier Id	**Fraction of unavailability due to NGSO**				
245	0.132	0.132			
232	0.230	0.159	0.158	0.130	

No links failed, at the provisional epfd limits, with earth station antenna diameters greater than 3 meters.

5.1.2 Apfd results

14/11GHz-band apfd limits were tested for satellite antenna beamwidths of 1, 2 and 3 degrees. The minimum availability used to test the 10% criteria, for all of the links, was 99.99%. In all cases the initial limits (Table 4-2) could be loosened. The new limits where all carriers passed the 10% criteria, are shown in the tables in bold. In the case of the 2 degree beamwidth, the apfd value could be loosened more than 5 dB from the initial limits. This may indicate that there aren't sensitive link budgets in the annexes of document 4-9-11/TEMP/29 representative of a 2 degree satellite beamwidth.

TABLE 5.1.2-1

14/11GHz-band apfd limits for 1 degree beamwidth (1 dB minimum margin)

APFD %	APFD (dBW/m²/4KHz)		
100	-166	-171	-172
Carrier ID	**Fraction of unavailability due to NGSO**		
243	0.112		
244	0.112		
245	0.112		
246	0.112		
247	0.112		
248	0.112		
242	0.141	0.108	

TABLE 5.1.2-2

14/11GHz-band apfd limits for 2 degree beamwidth (1 dB minimum margin)

APFD %	APFD (dBW/m²/4KHz)	
100	-161	-162
Carrier ID	**Fraction of unavailability due to NGSO**	
234	0.100	
235	0.100	
236	0.112	
238	0.111	
241	0.109	
14	0.108	

TABLE 5.1.2-3

14/11GHz-band apfd limits for 3 degree beamwidth (1 dB minimum margin)

APFD %	APFD ($dBW/m^2/4KHz$)				
100	-156	-161	-162	-165	**-166**
Carrier ID	**Fraction of unavailability due to NGSO**				
222	0.116				
223	0.116				
224	0.116				
34	0.250	0.132	0.120	0.100	
220	0.114				
221	0.114				
225	0.114				
226	0.114				
227	0.114				
232	0.114				
38	0.142	0.113	0.111		
39	0.140	0.111	0.109		
228	0.139	0.112			
229	0.139313	0.112231			
230	0.139313	0.112231			
231	0.139313	0.112231			

5.2 Sensitive Links and New Epfd and Apfd limits

The epfd and apfd limits are designed to protect the GSO FSS. It is assumed that protection will be provided for all the most sensitive GSO FSS links. In terms of the 10% NGSO criteria, sensitive links are a function of earth station location, system margin and link availability. The most sensitive links are in dry climates, have high altitudes, high elevation angles, and operate with a minimum rain margin and link availability.

In order to develop new epfd and apfd limits the 41 most sensitive geographic locations, from the database of 2700 urban centers (Section 3.2.2), were selected. These locations were selected by sorting in order of driest rain zone, highest altitude and highest elevation angle. Information on the most sensitive links, from the database of 2700 urban centers, is contained in Annex 1. A link in Denver was also included. The Denver link was used in Annex 3 and 4, for calculating the initial epfd/apfd limits using Methodology B'.

A maximum elevation angle for the earth station was calculated, for the sensitive links, assuming that the satellite is at the same longitude as the earth station. The minimum received temperatures in Table 3.2.1-2, and for the epfd calculation, the minimum link availabilities in Table 5-1 were assumed for all the links. For determining apfd limits, an availabilities of 99.99% (0.01% unavailability) was assumed. As in the previous sections a minimum link margin of 1 dB was assumed. The sensitive links are assumed to have just enough power to meet the required link availability given rain and NGSO interference.

Annex 2 summarizes the epfd and apfd test results using the 41 most sensitive links. As in Section 5.1 each column in the Annex 2 tables tests a different epfd or apfd limit. The tables indicate the fraction of unavailability due to NGSO interference for the links that fail the 10% criteria. The last column in each table shows the epfd (apfd) limits that result in all the sensitive links passing the 10% criteria. The epfd limits are shown in Tables A2-1 to A2-7. Apfd limits are shown in Tables A2-8 to A2-10.

Table A2-1 shows the results for a GSO earth station with a 0.6 m antenna. The starting epfd limit is shown in column 1. All the sensitive links failed the 10% criteria at this epfd level. All three (long term, short term and 100% not to be exceeded) epfd limits were then varied in one dB steps, in succesive columns of the table, until all the sensitive links passed the 10% criteria.

In the last column of the table, limit values (long term, short term, and 100% not to be exceeded) were independently varied to see if the final limits could be made any looser and still have all the sensitive links pass the 10% criteria. It was determined that the long term and short limits could be loosened as shown in the last column of Table A2-1. Furthermore, this turned out to be a consistent result for all the other earth station antenna sizes as shown in Tables A2-3 to A2-7.

Table A2-2 shows the results for a GSO earth station with a 0.6 m antenna and the minimum margin relaxed from 1 dB to 2 dB. In very dry rain zones the GSO links require very little margin to operate at the required availability. Table A2-2 demonstrates the effect of adding one dB of margin to these very sensitive links. As can be seen in the last column of Table A2-2 the final epfd limits can be loosened 4 dB compared to Table A2-1.

Tables 5.2-1 and 5.2-2 show the final 14/11GHz-band epfd and apfd values required to protect all the sensitive links.

TABLE 5.2-1

Proposed Aggregate 14/11GHz-band epfd Limits

	Provisional Single Entry EPFD Limits (WRC-97)		Proposed Aggregate NGSO system EPFD limits	
Antenna Diameter (m)	EPFD ($dBW/m^2/4$ KHz)	Percent of time not to exceed (%)	EPFD ($dBW/m^2/4K$ Hz)	Percent of time not to exceed (%)
0.6	-179	99.7	-183	99
0.6	-170	99.999	-173	99.97
0.6	-170	100	-172	100
1.2			-189	99
1.2			-178	99.98
1.2			-177	100
1.8			-192	99
1.8			-181	99.99
1.8			-180	100
3	-192	99.9	-197	99
3	-186	99.97		
3	-173	99.999	-185	99.995
3	-170	100	-184	100
7			-203	99
7			-191	99.999
7			-190	100
10	-195	99.97	-206	99
10	-178	99.999	-194	99.999
10	-170	100	-193	100

TABLE 5.2-2 PROPOSED AGGREGATE 14/11GHZ-BAND APFD LIMITS

Satellite Receive Antenna	Provisional Single Entry APFD Limits (WRC-97)		Modified Aggregate NGSO system apfd limits	
Beamwidth (degrees)	APFD ($dBW/m^2/4$ KHz)	Percent of time not to exceed (%)	APFD ($dBW/m^2/4$ KHz)	Percent of time not to exceed (%)
1	-170	100	-186	100
2			-181	100
3			-177	100

5.3 Sensitivity Study

It has not been determined that the link budgets in Doc. 4-9-11/TEMP/29 are representative of all existing and future sensitive links. For example, many of the link budgets have high availabilities and could operate with lower availabilities. Also, the link budgets are not representative of all geographic locations and there is no way to determine the number of each type of link in operation. Finally, the link budgets represent static cases and are unlikely to be representative of the vast number of link budgets in operation or of a dynamic industry whose requirements may change daily.

In order to test the breadth of representation of the 4-9-11/TEMP/29 links and to rectify some of the deficiencies in the JTG 4-9-11/TEMP/29 annexes, this analysis assumes that the number of earth stations in operation in different geographic regions will be proportional to populations in urban centers around the world. A most sensitive link is defined in each urban center and the Annex 3 epfd limits are tested. Distributions for urban centers and population versus rain zone are discussed in section 3.2.2.

Urban centers in rain zones A through M were used in the evaluations. Table 5.2-1 shows the number of urban centers in each rain zone. There were a total of 2002 urban centers used in the evaluations.

TABLE 5.2-1

Urban centers in each rain zone

Rain Zone	Urban Centers
A	13
B	6
C	91
D	64
E	529
F	59
G	5
H	150
J	42
K	803
L	23
M	217

5.3.1 Rain Zone Sensitivity

In this section the sensitivity of the epfd limits to rain zone is examined. Table 5.3-1 shows the epfd limits evaluated and should be used as a key to the results in Figures 5.3.1-1 to 5.3.1-5. The second column of the table shows the percentage of availability not to exceed. As in the previous tests the percentage the epfd limit can be exceeded was not varied. Instead, the epfd limit values were varied in one dB steps. The tests stopped when links in all urban centers passed the 10% criteria. The antennas tested were 0.6, 1.2, 1.8, 3, 7, and 10 m diameters with a system temperature of 188 K.

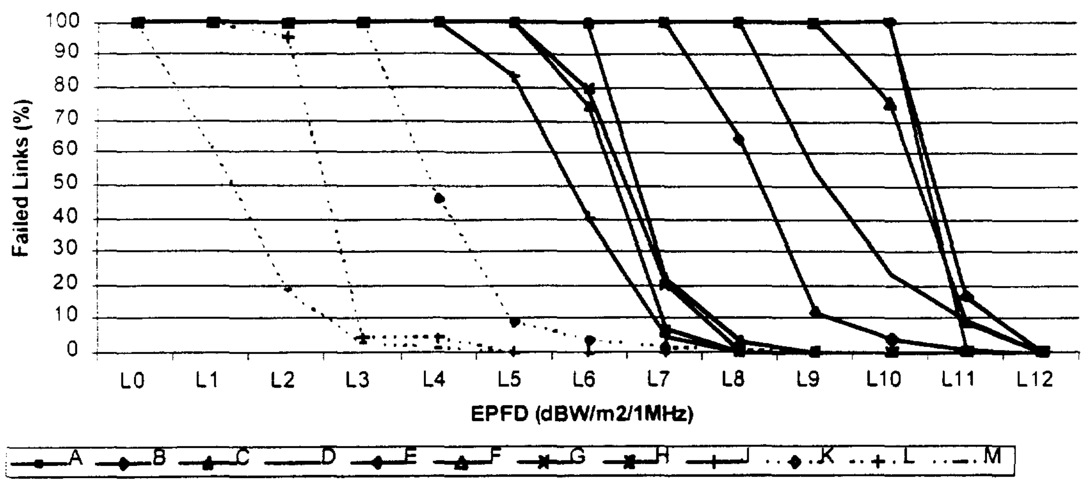
TABLE 5.3-1

Epfd limits evaluated in Figures 5.3.1-1 to 5.3.1-5

	EPFD	**EPFD (dBW/m2/4 kHz)**												
Figure	%	L0	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12
	99	-171	-172	-173	-174	-175	-176	-177	-178	-179	-180	-181	-182	-183
5.3.1-1	99.97	-161	-162	-163	-164	-165	-166	-167	-168	-169	-170	-171	-172	-173
(0.6 m)	100	-160	-161	-162	-163	-164	-165	-166	-167	-168	-169	-170	-171	-172
	99	-177	-178	-179	-180	-181	-182	-183	-184	-185	-186	-187	-188	-189
5.3.1-2	99.98	-166	-167	-168	-169	-170	-171	-172	-173	-174	-175	-176	-177	-178
(1.2 m)	100	-165	-166	-167	-168	-169	-170	-171	-172	-173	-174	-175	-176	-177
	99	-180	-181	-182	-183	-184	-185	-186	-187	-188	-189	-190	-191	-192
5.3.1-3	99.99	-169	-170	-171	-172	-173	-174	-175	-176	-177	-178	-179	-180	-181
(1.8 m)	100	-168	-169	-170	-171	-172	-173	-174	-175	-176	-177	-178	-179	-180
	99	-185	-186	-187	-188	-189	-190	-191	-192	-193	-194	-195	-196	-197
5.3.1-4	99.995	-173	-174	-175	-176	-177	-178	-179	-180	-181	-182	-183	-184	-185
(3 m)	100	-172	-173	-174	-175	-176	-177	-178	-179	-180	-181	-182	-183	-184
	99	-191	-192	-193	-194	-195	-196	-197	-198	-199	-200	-201	-202	-203
5.3.1-5	99.999	-179	-180	-181	-182	-183	-184	-185	-186	-187	-188	-189	-190	-191
(7 m)	100	-178	-179	-180	-181	-182	-183	-184	-185	-186	-187	-188	-189	-190
	99	-194	-195	-196	-197	-198	-199	-200	-201	-202	-203	-204	-205	-206
5.3.1-6	99.999	-182	-183	-184	-185	-186	-187	-188	-189	-190	-191	-192	-193	-194
(10 m)	100	-181	-182	-183	-184	-185	-186	-187	-188	-189	-190	-191	-192	-193

Figure 5.3.1-1 shows the result of the epfd evaluation for a 0.6 m antenna with a system temperature of 188 K and a one dB minimum margin. The figure indicates the percentage of cities failing the 10% NGSO requirement for each epfd limit as a function of rain zone. As expected, the more sensitive links are in the dryer rain zones. An epfd level equal to L12 is required to protect all urban centers in rain zone A and B. Notice that there is about a seven dB spread for full protection of links in rain zone M compared to rain zone A.

Figure 5.3.1-1: Percentage of Links Failing the 10% Criteria (0.6 m antenna, Tsys=188 K, 1 dB min margin)



Figures 5.3.1-2, 5.3.1-3 and 5.3.1-4 show the evaluation results for a 1.2, 1.8 and 3 m antenna respectively. In general the curves show the same trends as was seen in Figure 5.3.1-1. Again there is about a seven dB spread between protection of all cities in rain zone M and all cities in rain zone A.

Figure 5.3.1-2: Percentage of Links Failing the 10% Criteria (1.2 m antenna, Tsys=188 K, 1 dB min margin)

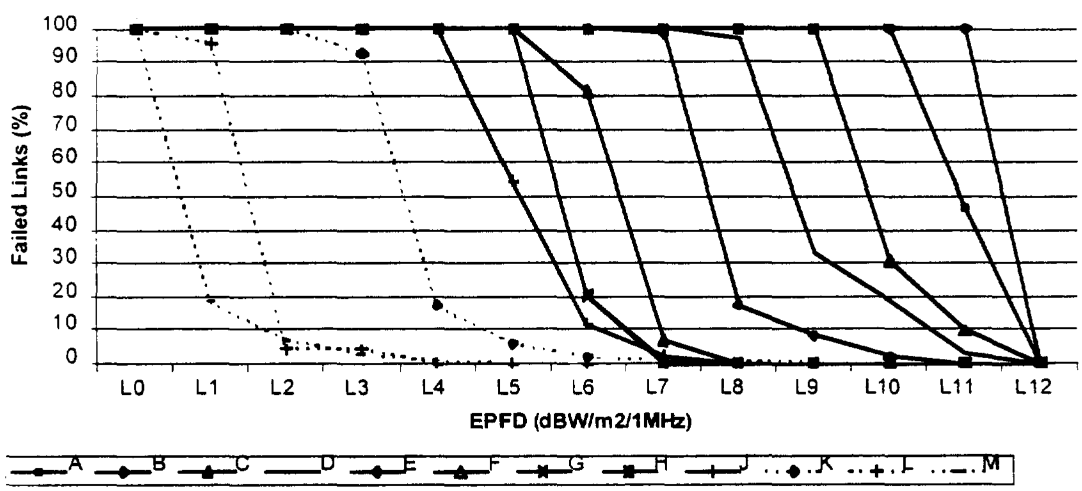


Figure 5.3.1-3: Percentage of Links Failing the 10% Criteria (1.8 m antenna, Tsys=188 K, 1 dB min margin)

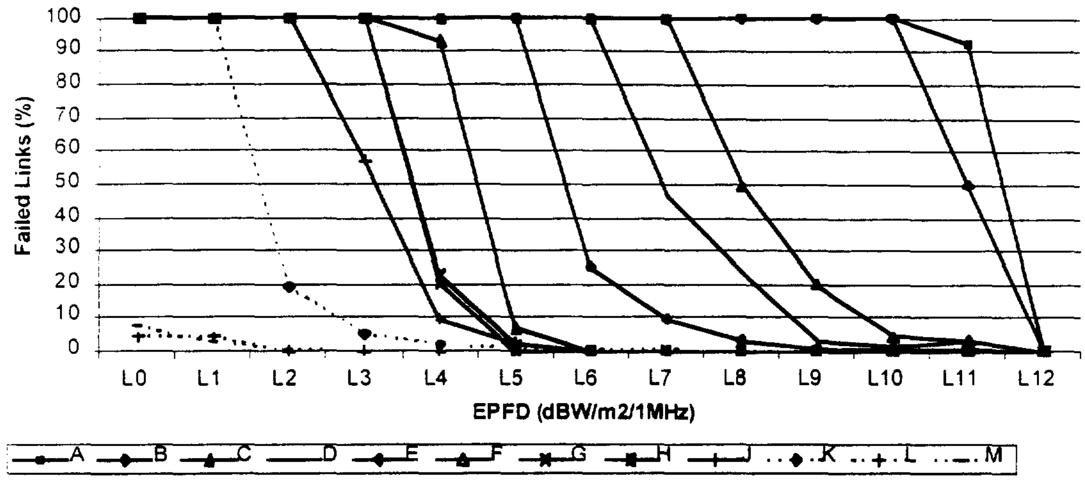


Figure 5.3.1-4: Percentage of Links Failing the 10% Criteria (3.0 m antenna, Tsys=188 K, 1 dB min margin)

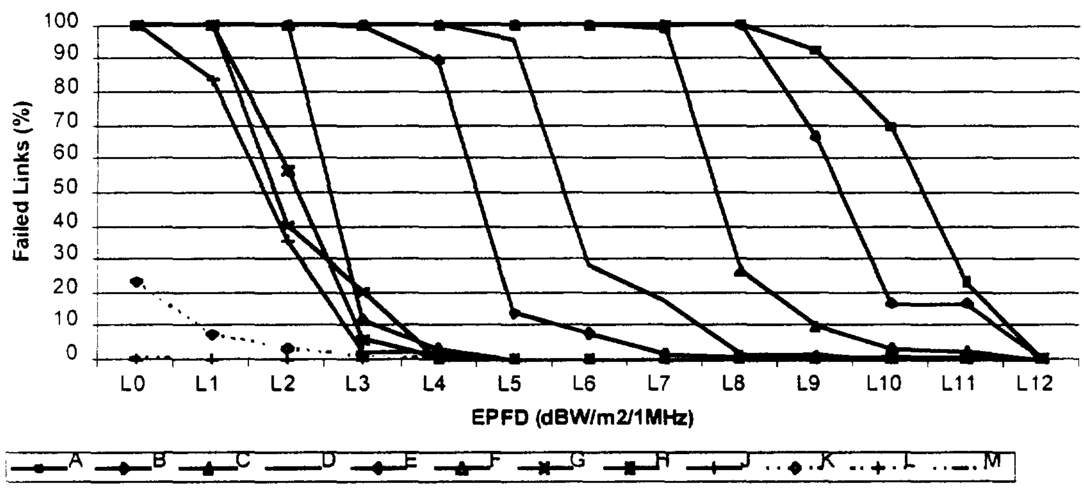


Figure 5.3.1-5 and 5.3.1-6 shows the evaluation results for a 7 m and 10 m antenna, respectively. Notice that as the antenna size increases there is a slightly slower decay from 100 % of link failures to 0% of link failures

Figure 5.3.1-5: Percentage of Links Failing the 10% Criteria (7.0 m antenna, Tsys=188 K, 1 dB min margin)

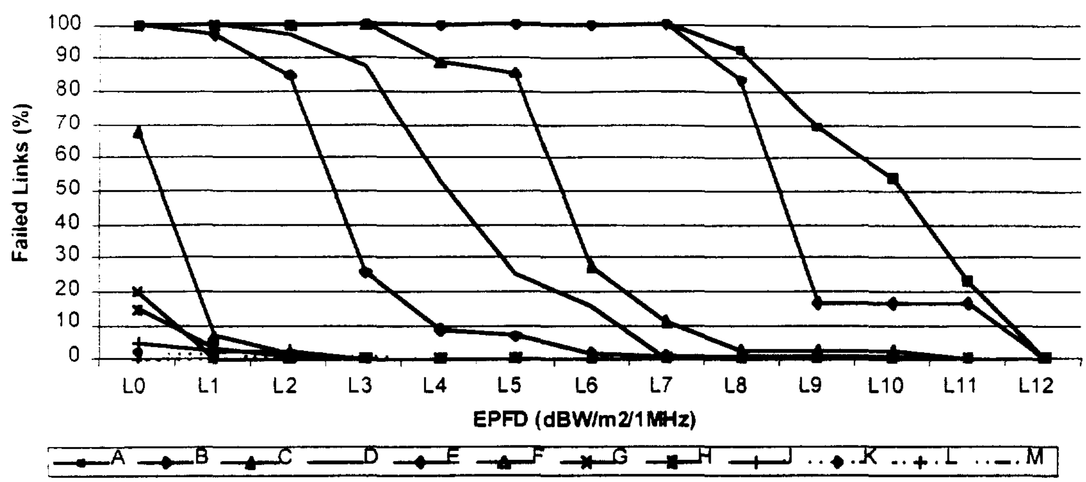
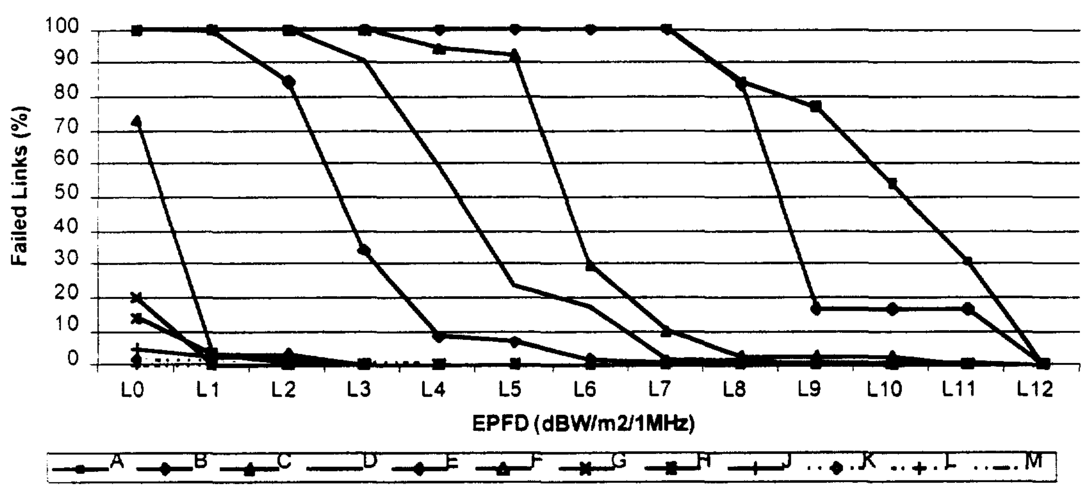


Figure 5.3.1-6: Percentage of Links Failing the 10% Criteria (10.0 m antenna, Tsys=188 K, 1 dB min margin)



5.3.2 Sensitivity in Temperature

The analysis in this section is the same as in Section 5.3.1 except that the earth station system temperature has been increased for all links by a factor of three from 188 K to 564 K. New results were then generated for the 0.6 m and 10 m earth station antennas. Table 5.3.2-1 shows the epfd limits evaluated and should be used as a key to the results in Figures 5.3.2-1 to 5.3.2-2. The higher temperature was included to demonstrate the sensitivity of the analysis to this parameter.

TABLE 5.3.2-1

Epfd limits evaluated in Figures 5.3.2-1 to 5.3.2-2

	EPFD	EPFD (dBW/m2/4 kHz)												
Figure	%	L0	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12
	99	-171	-172	-173	-174	-175	-176	-177	-178	-179	-180	-181	-182	-183
5.3.2-1	99.97	-161	-162	-163	-164	-165	-166	-167	-168	-169	-170	-171	-172	-173
(0.6 m)	100	-160	-161	-162	-163	-164	-165	-166	-167	-168	-169	-170	-171	-172
	99	-194	-195	-196	-197	-198	-199	-200	-201	-202	-203	-204	-205	-206
5.3.2-2	99.999	-182	-183	-184	-185	-186	-187	-188	-189	-190	-191	-192	-193	-194
(10 m)	100	-181	-182	-183	-184	-185	-186	-187	-188	-189	-190	-191	-192	-193

Figure 5.3.2-1 shows the result of the epfd evaluation for a 0.6 m antenna with a system temperature of 564 K. This result should be compared to Figure 5.3.1-1 for a system temperature of 188 K. Notice that increasing the temperature by a factor of three allows the epfd limits to be relaxed by about 5 dB (from L12 to L7) such that cities in all of the rain zones pass the 10% criteria.

Figure 5.3.2-2: Percentage of Links Failing the 10% Criteria (10 m antenna, Tsys=564 K, 1 dB min margin)

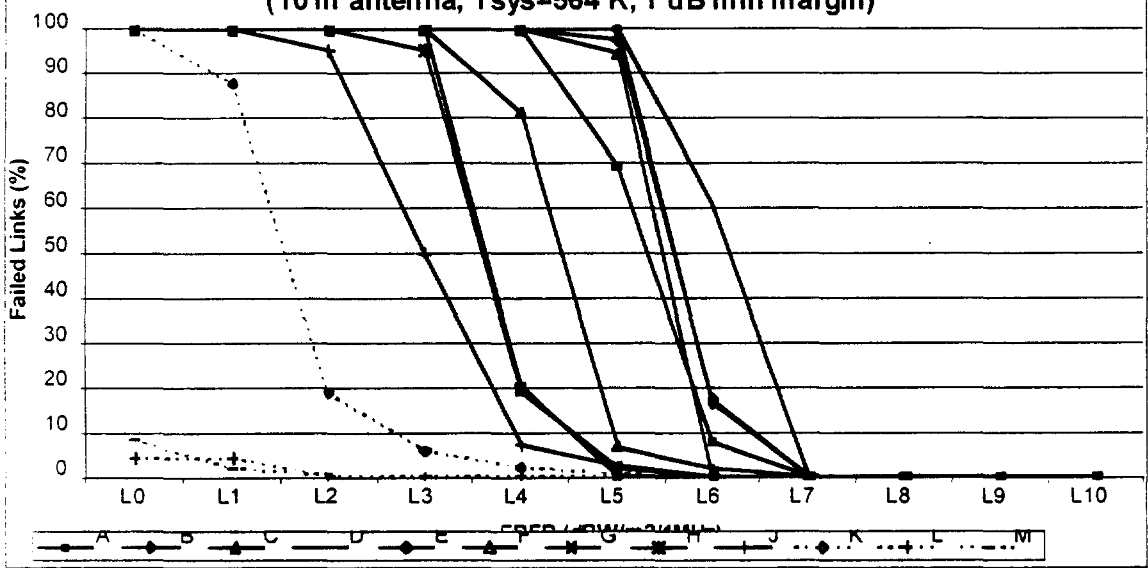


Figure 5.3.2-2 shows the result of the epfd evaluation for a 10 m antenna with a system temperature of 564 K. This result should be compared to Figure 5.3.1-6 for a system temperature of 188 K. Notice that in this case, the increase in system temperature results in a 4 dB relaxation of the epfd limits such that all cities in all of the rain zones pass the 10% criteria.

Figure 5.3.2-2: Percentage of Links Failing the 10% Criteria (10 m antenna, Tsys=564 K, 1 dB min margin)

5.3.3 Elevation Angle Sensitivity

The analysis in this section is the same as in section 5.3.1 except that instead of using the maximum earth station elevation angle, a 20 degree nominal elevation angle was assumed. For a few locations, however, the maximum elevation angle was less than 20 degrees. These locations used a maximum elevation angle. The low elevation angle was included to demonstrate the sensitivity of the analysis to this parameter. The antennas tested were 0.6 and 10 m diameters with a system temperature of 188 K. Table 5.3.3-1 shows the epfd limits evaluated and should be used as a key to the results in Figures 5.3.3-1 to 5.3.3-2.

TABLE 5.3.3-1

Epfd limits evaluated in Figures 5.3.3-1 to 5.3.3-2

	EPFD	**EPFD (dBW/m2/4 kHz)**												
Figure	%	L0	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12
5.3.2-1	99	-171	-172	-173	-174	-175	-176	-177	-178	-179	-180	-181	-182	-183
	99.97	-161	-162	-163	-164	-165	-166	-167	-168	-169	-170	-171	-172	-173
	100	-160	-161	-162	-163	-164	-165	-166	-167	-168	-169	-170	-171	-172
5.3.2-2	99	-194	-195	-196	-197	-198	-199	-200	-201	-202	-203	-204	-205	-206
	99.999	-182	-183	-184	-185	-186	-187	-188	-189	-190	-191	-192	-193	-194
	100	-181	-182	-183	-184	-185	-186	-187	-188	-189	-190	-191	-192	-193

Figure 5.3.3-1 shows the result of the epfd evaluation for a 0.6 m antenna with an elevation angle of 20 degrees. This result should be compared to Figure 5.3.1-1. Notice that changing the elevation angle reduced the final limit, required to protect all cities in all rain zones, by one dB. In general, the lower elevation angle has shifted the rain zone curves to the left by 2 to 3 dB.

Figure 5.3.3-1: Percentage of Links Failing the 10% Criteria (Elevation Angle <= 20 deg, 0.6 m antenna, Tsys=188 K, 1 dB min margin)

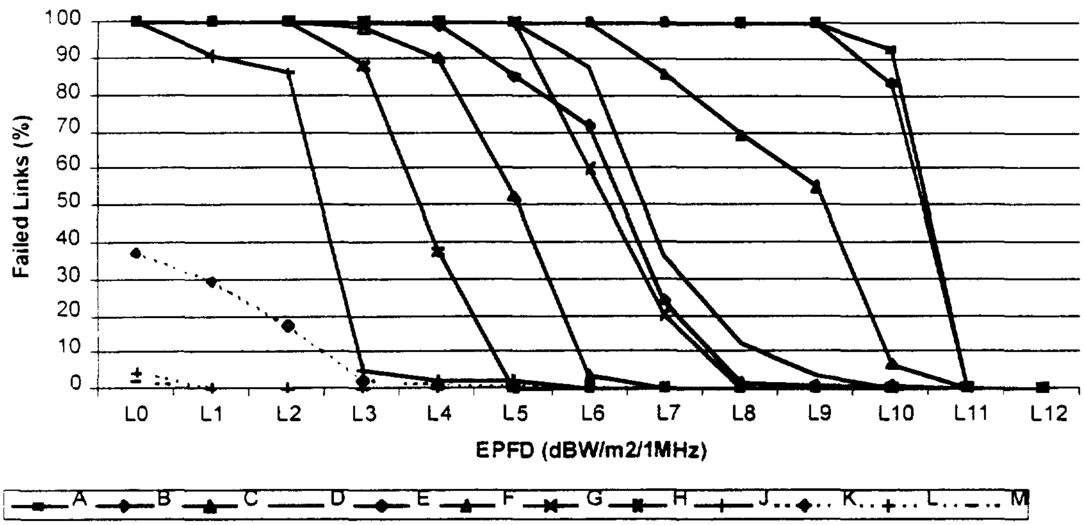
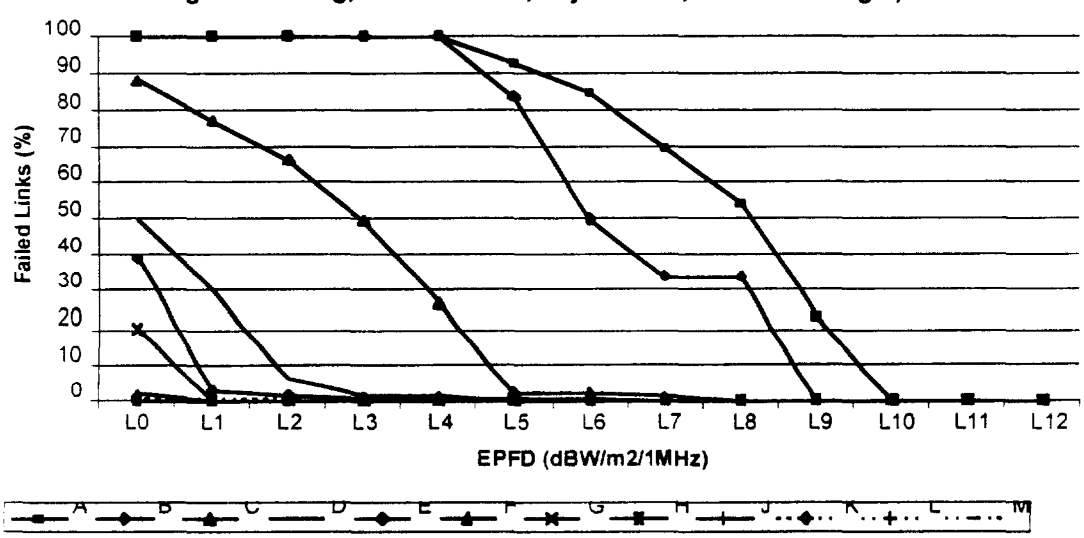


Figure 5.3.3-2 shows the result of the epfd evaluation for a 10 m antenna with an elevation angle of 20 degrees. This result should be compared to Figure 5.3.1-6. Notice that changing the elevation angle made about a 2 dB difference in the final limit requred to protect all cities in all rain zones.

Figure 5.3.3-2: Percentage of Links Failing the 10% Criteria (Elevation Angle <= 20 deg, 10 m antenna, Tsys=188 K, 1 dB min margin)



ANNEX 1

World Urban Population Centers

Country	City	Long	Lat	Pop	RZ	Alt	Country	City	Long	Lat	Pop	RZ	Alt
China	Urumqi	87.083	43	1084060	a	1962	Russian Fed.	Murmansk	33.133	68.983	426000	c	140
China	Shihezi	86.167	44.317	563740	a	403	Russian Fed.	Nizhny_Tagil	59.967	58	423000	c	233
Saudi_Arabia	Jeddah	39.167	21.5	561104	a	105	Russian Fed.	Kirov	49.667	58.583	415000	c	135
China	Uhai	106.87	39.783	266620	a	1525	Russian Fed.	Arkhanglsk	41	64.667	412000	c	68
Russian Fed.	Petropavlovsk	158.72	53.05	248000	a	300	Russian Fed.	Cheboksary	47.2	56.133	402000	c	113
Saudi_Arabia	Riyadh	46.767	24.65	198186	a	640	Saudi_Arabia	Makkah	39.817	21.433	366801	c	335
Egypt	Aswan	32.933	24.083	196000	a	213	Russian Fed.	Ashkhabad	58.4	37.967	366000	c	200
China	Yumen	97.717	39.9	195290	a	2070	Russian Fed.	Kurgan	65.333	55.5	348000	c	128
Russian Fed.	Norilsk	88.033	69.35	181000	a	188	Russian Fed.	Chita	113.58	52.05	342000	c	730
Russian Fed.	Nakhodka	-179	71.167	152000	a	535	Russian Fed.	Makhachkala	47.5	42.983	311000	c	80
Russian Fed.	Magadan	150.83	59.633	145000	a	295	Russian Fed.	Cherepovets	37.833	59.15	309000	c	113
Russian Fed.	Stakhanov	101.67	71.767	112000	a	30	Russian Fed.	Dzhambul	71	43.167	308000	c	468
Russian Fed.	Vorkuta	64	67.45	110000	a	150	Ethiopia	Asmara	38.967	15.333	307070	c	1829
US	Salt_Lake_Cty	-111.9	40.75	1041400	b	1316	Egypt	Assyut	31.117	27.233	291000	c	52
US	Spokane	-117.4	47.667	356900	b	669	Russian Fed.	Namangan	71.683	41.391	283000	c	1400
US	Provo	-111.6	40.267	240500	b	2246	Russian Fed.	Andizhan	72	41.167	281000	c	830
China	Kuytun	85	44.5	239870	b	533	Russian Fed.	Vologda	39.917	59.167	273000	c	150
US	Ogden	-112.2	40.78	76570	b	1322	Russian Fed.	Kostroma	40.983	57.767	273000	c	105
China	Korla	86.167	41.8	117690	b	1205	UnitedArabEm	Dubai	55.283	25.233	265702	c	-1

Russian Fed.	Gorky	45.067	57.6	1409000 c	90	Egypt	Suez	32.55	29.983	265000 c	45
Russian Fed.	Sverdlovsk	60.583	56.867	1315000 c	270	Russian Fed.	Petrozavodsk	34.317	61.767	259000 c	160
Afghanistan	Kabul	69.167	34.5	1297000 c	2513	China	Yining	81.467	43.833	257280 c	1015
Iran	Mashhad	59.567	36.267	1120000 c	1088	China	Kashi	76	39.483	256890 c	1348
Russian Fed.	Chelyabinsk	61.417	55.2	1107000 c	210	Russian Fed.	Andropov	38.833	58.05	252000 c	105
Russian Fed.	Alma-Ata	76.917	43.317	1088000 c	775	Russian Fed.	Volzhsky	47.85	46.65	250000 c	-30
Russian Fed.	Perm	56.167	58.017	1065000 c	150	Russian Fed.	Bratsk	101.83	56.333	245000 c	483
Russian Fed.	Kazan	49.167	55.75	1057000 c	75	UnitedArabEm	Abu_Dhabi	54.417	24.467	242975 c	-1
Saudi_Arabia	Ta'if	40.35	21.25	666840 c	1905	Russian Fed.	Yoshkar-Ola	47.867	56.633	236000 c	60
Russian Fed.	Yaroslavl	39.867	57.567	630000 c	120	US	Anchorage	-149.8	61.167	235000 c	80

Country	City	Long	Lat	Pop	RZ	Alt	Country	City	Long	Lat	Pop	RZ	Alt
Russian Fed.	Frunze	74.833	42.667	617000	c	2113	Russian Fed.	Severodvinsk	39.833	64.566	234000	c	30
Russian Fed.	Astrakhan	48.067	46.367	503000	c	-30	Russian Fed.	Sumgait	49.633	40.583	228000	c	-30
Russian Fed.	Ivanovo	41.99	57	476000	c	120	Egypt	Faiyum	30.833	29.317	227000	c	74
Russian Fed.	Breznev	52.317	55.7	459000	c	120	Russian Fed.	Syktykar	50.75	61.7	218000	c	60
Russian Fed.	Tyumen	65.483	57.183	440000	c	60	Qatar	Doha	51.535	25.217	217294	c	30
Russian Fed.	Surgut	73.333	61.217	215000	c	90	Russian Fed.	Solikamsk	56.75	59.667	107000	c	135
Sudan	Port_Sudan	37.117	19.633	205000	c	152	Russian Fed.	Novocheboksars	47.45	56.083	106000	c	90
Russian Fed.	Zlatoust	59.633	55.167	205000	c	595	Russian Fed.	Kineshma	42.133	57.467	105000	c	120
Russian Fed.	Osh	72.817	40.617	204000	c	915	Russian Fed.	Serov	60.533	59.7	103000	c	128
Chile	Antofagasta	-70.38	-23.67	203067	c	252	Russian Fed.	Uhta	53.733	63.55	102000	c	90
Egypt	Menia	30.75	28.001	203000	c	43	UnitedArabEm	Ai-Ain	55.75	24.183	101663	c	455
Russian Fed.	Kamensk-Uralsk	61.817	56.483	202000	c	180	Saudi_Arabia	Huful	49.567	25.333	101271	c	165
Russian Fed.	Nizenvartovsk	76.667	60.95	200000	c	90	Russian Fed.	Ust-Ilimsk	102.65	58.05	101000	c	305
Russian Fed.	Fergana	71.317	40.383	199000	c	490	Russian Fed.	Votkinsk	54	57	100000	c	128
Russian Fed.	Berezniki	56.817	59.433	198000	c	120	Namibia	Windhoek	17.1	-22.57	36051	c	1829
Russian Fed.	Yakutsk	129.83	62.167	184000	c	105	Russian Fed.	Sarapul	60.967	64.25	110000	c	90
Russian Fed.	Nizhnekamsk	51.783	55.6	177000	c	90	Russian Fed.	Taldi-Kurgan	78.383	45.033	109000	c	835
Afghanistan	Herat	62.167	34.333	168200	c	988	Bahrain	Manama	50.568	26.2	108684	c	-10
Egypt	Beni-Suef	31.083	29.083	163000	c	27	Iran	Sabzewar	57.633	36.217	108000	c	958
Russian Fed.	Yuzhno-Sakhali	142.75	46.967	163000	c	120	UnitedArabEm	Sharjah	55.433	25.333	125149	c	30
Russian Fed.	Miass	60.133	55	162000	c	393	Russian Fed.	Margelan	71.75	40.5	124000	c	460
Chile	Arica	-70.29	-18.5	158422	c	308							
Sudan	Kassala	36.417	15.4	149000	c	1268							

Russian Fed.	Guryev	51.983	47.133	147000 c	-30
Egypt	Kena	32.7	26.133	142000 c	72
Egypt	Sohag	31.7	26.55	141000 c	64
Yemen	Sana	44.233	15.4	140339 c	2590
Russian Fed.	Pervouralsk	59.967	56.983	138000 c	335
Mauritania	Nouakchott	-17.05	20.9	134986 c	5
Saudi_Arabia	Dammam	50.1	26.417	127844 c	60
Chile	Iquique	-70.13	-20.25	127491 c	144

ANNEX 2

14/11GHz epfd Link Data for 4kHz Bandwidth

TABLE A2-1

14/11GHz-band epfd limits for 0.6 m Antenna from Sensitive Links (1 dB Minimum Margin)

Fraction of Unavailability due to NGSO

Antenna	**size =0.6m**										
	% Can't Exceed	**EPFD (dBW/m²/4KHz)**									
	99	*-176*	-177	-178	-179	-180	-181	-182	-183	-184	**-183**
	99.97	*-169*	-170	-171	-172	-173	-174	-175	-176	-177	**-173**
	100	*-163*	-164	-165	-166	-167	-168	-169	-170	-171	**-172**
Country	**City**										
US	Denver	0.327	0.261	0.212	0.211	0.159	0.158	0.158	0.101		
China	Urumqi	0.755	0.713	0.704	0.695	0.689	0.686	0.683			
China	Yumen	0.686	0.603	0.586	0.568	0.559	0.552	0.545			
China	Uhai	0.585	0.441	0.418	0.379	0.359	0.358	0.339			
Saudi_Arabia	Riyadh	0.609	0.475	0.438	0.420	0.403	0.386	0.368			
Russian Fed.	Nakhodka	0.605	0.470	0.431	0.413	0.395	0.376	0.359			
China	Shihezi	0.589	0.446	0.424	0.386	0.367	0.366	0.347			
Russian Fed.	Petropavlovsk	0.588	0.442	0.419	0.380	0.359	0.359	0.340			
Russian Fed.	Magadan	0.576	0.424	0.375	0.352	0.329	0.305	0.305	0.282		
Egypt	Aswan	0.558	0.405	0.361	0.335	0.310	0.285	0.284	0.258		
Russian Fed.	Norilsk	0.555	0.399	0.365	0.340	0.315	0.289	0.289	0.264		
Russian Fed.	Vorkuta	0.561	0.425	0.370	0.346	0.321	0.297	0.297	0.273		
Saudi_Arabia	Jeddah	0.531	0.391	0.309	0.275	0.242	0.241	0.208	0.207		
Russian Fed.	Stakhanov	0.660	0.559	0.538	0.527	0.506	0.497	0.497			
US	Provo	0.552	0.396	0.368	0.343	0.319	0.295	0.294			
US	Garland	0.555	0.399	0.365	0.340	0.314	0.289	0.289	0.264		
US	Salt_Lake_City	0.549	0.396	0.359	0.333	0.306	0.280	0.279	0.253		
China	Korla	0.527	0.388	0.307	0.273	0.239	0.238	0.204	0.203		
US	Spokane	0.493	0.394	0.303	0.267	0.231	0.230	0.194	0.193		
China	Kuytun	0.558	0.406	0.361	0.335	0.310	0.284	0.284	0.258		
Yemen	Sana	0.595	0.450	0.429	0.410	0.374	0.373	0.356			
Afghanistan	Kabul	0.589	0.447	0.425	0.387	0.369	0.368	0.349			
Russian Fed.	Frunze	0.486	0.407	0.300	0.262	0.224	0.223	0.185	0.184		
Saudi_Arabia	Ta'if	0.476	0.394	0.300	0.262	0.223	0.223	0.183	0.183		
Ethiopia	Asmara	0.479	0.397	0.301	0.264	0.227	0.226	0.189	0.189		
Namibia	Windhoek	0.509	0.386	0.305	0.270	0.236	0.235	0.200	0.200		
Russian Fed.	Namangan	0.482	0.400	0.302	0.265	0.228	0.228	0.190	0.190		
China	Kashi	0.419	0.325	0.257	0.211	0.210	0.160	0.159	0.159	0.110	
Sudan	Kassala	0.425	0.342	0.261	0.212	0.212	0.167	0.166	0.166		
Iran	Mashhad	0.457	0.345	0.260	0.257	0.215	0.173	0.172	0.172		

China	Yining	0.419	0.325	0.257	0.211	0.210	0.160	0.160	0.160	0.111
Afghanistan	Herat	0.422	0.328	0.257	0.211	0.210	0.161	0.160	0.160	0.111
Iran	Sabzewar	0.433	0.336	0.257	0.211	0.211	0.165	0.165	0.164	0.118
Russian Fed.	Osh	0.418	0.336	0.257	0.211	0.210	0.163	0.163	0.163	0.116
Russian Fed.	Taldi-Kurgan	0.403	0.326	0.257	0.210	0.209	0.162	0.162	0.161	0.111
Russian Fed.	Andizhan	0.419	0.325	0.257	0.211	0.210	0.160	0.160	0.160	0.118
Russian Fed.	Alma-Ata	0.433	0.336	0.257	0.211	0.210	0.165	0.164	0.164	0.109
Russian Fed.	Chita	0.408	0.316	0.257	0.210	0.210	0.159	0.159	0.158	
Russian Fed.	Zlatoust	0.384	0.262	0.257	0.211	0.160	0.159	0.159	0.104	
Russian Fed.	Fergana	0.401	0.314	0.257	0.211	0.211	0.161	0.160	0.160	0.106
Russian Fed.	Bratsk	0.386	0.302	0.258	0.211	0.211	0.161	0.160	0.160	
Russian Fed.	Dzhambul	0.375	0.313	0.255	0.202	0.191	0.13	0.113		

TABLE A2-2

14/11GHz-band epfd limits for 0.6 m Antenna from Sensitive Links (2 dB Minimum Margin)

Antenna	**size =0.6m**						
	% Can't Exceed	**EPFD (dBW/m²/4KHz)**					
	99	*-176*	-177	-178	-179	-180	**-181**
	99.97	*-169*	-170	-171	-172	-173	**-174**
	100	*-163*	-164	-165	-166	-167	**-168**
Country	**City**	**Fraction of Unavailability due to NGSO**					
US	Denver	0.369	0.353	0.34	0.33		
China	Urumqi	0.918	0.917	0.92			
China	Yumen	0.912	0.912	0.91			
China	Uhai	0.832	0.832	0.83			
Saudi_Arabia	Riyadh	0.726	0.723	0.72			
Russian Fed.	Nakhodka	0.776	0.773	0.77	0.13	0.104	
China	Shihezi	0.759	0.755	0.75	0.12		
Russian Fed.	Petropavlovsk	0.742	0.739	0.74	0.11		
Russian Fed.	Magadan	0.73	0.726	0.72	0.1		
Egypt	Aswan	0.684	0.677	0.67			
Russian Fed.	Norilsk	0.659	0.654	0.65	0.11		
Russian Fed.	Vorkuta	0.671	0.665	0.66	0.12		
Saudi_Arabia	Jeddah	0.679	0.673	0.67			
Russian Fed.	Stakhanov	0.567	0.56	0.55			
US	Provo	0.81	0.809	0.81			
US	Garland	0.671	0.666	0.66	0.11		
US	Salt_Lake_City	0.671	0.665	0.66	0.12		
China	Korla	0.648	0.643	0.64	0.11		
US	Spokane	0.566	0.559	0.55	0.11		
China	Kuytun	0.54	0.53	0.52	0.11		
Yemen	Sana	0.659	0.654	0.65			
Afghanistan	Kabul	0.746	0.743	0.74			
Russian Fed.	Frunze	0.741	0.738	0.74	0.11		
Saudi_Arabia	Ta'if	0.517	0.505	0.5			
Ethiopia	Asmara	0.522	0.512	0.5			
Namibia	Windhoek	0.526	0.517	0.51			
Russian Fed.	Namangan	0.548	0.537	0.53			
China	Kashi	0.53	0.52	0.51			

Sudan	Kassala	0.45	0.435	0.43	0.42
Iran	Mashhad	0.468	0.454	0.44	0.44
China	Yining	0.489	0.478	0.47	0.46
Afghanistan	Herat	0.45	0.434	0.42	0.42
Iran	Sabzewar	0.452	0.438	0.43	0.42
Russian Fed.	Osh	0.459	0.447	0.44	0.43
Russian Fed.	Taldi-Kurgan	0.461	0.448	0.44	0.43
Russian Fed.	Andizhan	0.451	0.436	0.43	0.42
Russian Fed.	Alma-Ata	0.45	0.435	0.42	0.42
Russian Fed.	Chita	0.46	0.447	0.44	0.43
Russian Fed.	Zlatoust	0.439	0.423	0.41	0.4
Russian Fed.	Fergana	0.403	0.388	0.38	0.37
Russian Fed.	Bratsk	0.419	0.404	0.39	0.38
Russian Fed.	Dzhambul	0.405	0.39	0.38	0.37

TABLE A2-3

14/11GHz-band epfd limits for 1.2 m Antenna from Sensitive Links (1 dB Minimum Margin)

Antenna	**size =1.2m**										
	% Can't Exceed	**EPFD (dBW/m^2/4KHz)**									
	99	*-181*	-182	-183	-184	-185	-186	-187	-188	-189	**-189**
	99.98	*-174*	-175	-176	-177	-178	-179	-180	-181	-182	**-178**
	100	*-168*	-169	-170	-171	-172	-173	-174	-175	-176	**-177**
Country	**City**	**Fraction of Unavailability due to NGSO**									
US	Denver	0.313	0.273	0.227	0.177	0.165	0.11				
China	Yumen	0.842	0.716	0.648	0.631	0.617	0.610	0.604	0.599		
China	Uhai	0.841	0.711	0.644	0.628	0.614	0.603	0.597	0.593		
Saudi_Arabia	Riyadh	0.784	0.643	0.536	0.512	0.492	0.474	0.464	0.454		
Russian Fed.	Nakhodka	0.677	0.558	0.408	0.366	0.335	0.315	0.295	0.276		
China	Shihezi	0.707	0.573	0.427	0.389	0.360	0.337	0.320	0.304		
Russian Fed.	Petropavlovsk	0.697	0.568	0.423	0.384	0.355	0.332	0.309	0.296		
Russian Fed.	Magadan	0.687	0.564	0.414	0.374	0.344	0.320	0.301	0.287		
Egypt	Aswan	0.679	0.559	0.408	0.371	0.339	0.316	0.295	0.281		
Russian Fed.	Norilsk	0.639	0.542	0.400	0.343	0.313	0.285	0.264	0.247	0.234	
Russian Fed.	Vorkuta	0.609	0.518	0.395	0.326	0.294	0.268	0.245	0.227	0.213	
Saudi_Arabia	Jeddah	0.617	0.527	0.395	0.331	0.295	0.271	0.247	0.234	0.221	
Russian Fed.	Stakhanov	0.632	0.541	0.398	0.339	0.305	0.281	0.258	0.242	0.229	
US	Provo	0.537	0.442	0.353	0.294	0.257	0.232	0.209	0.187	0.176	
US	Garland	0.761	0.616	0.497	0.470	0.447	0.428	0.413	0.402		
US	Salt_Lake_City	0.618	0.528	0.394	0.331	0.296	0.271	0.248	0.234	0.221	
China	Korla	0.617	0.527	0.395	0.331	0.296	0.271	0.247	0.234	0.221	
US	Spokane	0.604	0.513	0.393	0.324	0.291	0.261	0.241	0.223	0.209	
China	Kuytun	0.536	0.440	0.353	0.294	0.257	0.232	0.209	0.187	0.176	
Yemen	Sana	0.511	0.415	0.328	0.286	0.249	0.224	0.200	0.181	0.163	
Afghanistan	Kabul	0.797	0.709	0.402	0.364	0.323	0.28	0.214	0.136		
Russian Fed.	Frunze	0.806	0.725	0.399	0.362	0.321	0.25	0.215	0.136		
Saudi_Arabia	Ta'if	0.586	0.398	0.311	0.268	0.223	0.17	0.159			
Ethiopia	Asmara	0.546	0.434	0.310	0.269	0.223	0.17	0.158			
Namibia	Windhoek	0.566	0.457	0.311	0.269	0.223	0.17	0.158			

Russian Fed.	Namangan	0.582	0.451	0.313	0.272	0.226	0.18	0.160
China	Kashi	0.583	0.476	0.311	0.270	0.224	0.17	0.161
Sudan	Kassala	0.468	0.311	0.269	0.225	0.175	0.16	0.102
Iran	Mashhad	0.460	0.312	0.272	0.226	0.177	0.17	0.106
China	Yining	0.526	0.387	0.274	0.229	0.218	0.17	0.110
Afghanistan	Herat	0.464	0.311	0.269	0.225	0.175	0.16	0.102
Iran	Sabzewar	0.491	0.312	0.270	0.225	0.175	0.16	0.103
Russian Fed.	Osh	0.480	0.362	0.272	0.226	0.177	0.16	0.107
Russian Fed.	Taldi-Kurgan	0.490	0.311	0.271	0.225	0.176	0.16	0.105
Russian Fed.	Andizhan	0.479	0.311	0.270	0.224	0.174	0.16	0.102
Russian Fed.	Alma-Ata	0.464	0.311	0.269	0.225	0.175	0.16	0.102
Russian Fed.	Chita	0.482	0.364	0.271	0.226	0.177	0.16	0.105
Russian Fed.	Zlatoust	0.464	0.312	0.269	0.223	0.173	0.16	0.100
Russian Fed.	Fergana	0.344	0.308	0.230	0.220	0.168	0.15	
Russian Fed.	Bratsk	0.359	0.309	0.268	0.222	0.171	0.16	
Russian Fed.	Dzhambul	0.344	0.308	0.266	0.220	0.169	0.15	

TABLE A2-4

14/11GHz-band epfd limits for 1.8 m Antenna from Sensitive Links (1 dB Minimum Margin)

Antenna	**size =1.8m**										
	% Can't Exceed	**EPFD (dBW/m^2/4KHz)**									
	99	*-185*	-186	-187	-188	-189	-190	-191	-192	-193	**-192**
	99.99	*-176*	-177	-178	-179	-180	-181	-182	-183	-184	**-181**
	100	*-171*	-172	-173	-174	-175	-176	-177	-178	-179	**-180**
Country	**City**	**Fraction of Unavailability due to NGSO**									
US	Denver	0.269	0.226	0.185	0.137	0.117					
China	Urumqi	0.882	0.810	0.663	0.492	0.469	0.457	0.447	0.441		
China	Yumen	0.879	0.807	0.663	0.491	0.465	0.449	0.441	0.433		
China	Uhai	0.807	0.729	0.583	0.410	0.363	0.342	0.327	0.316	0.306	
Saudi_Arabia	Riyadh	0.641	0.538	0.428	0.321	0.254	0.227	0.206	0.188	0.174	
Russian Fed.	Nakhodka	0.680	0.579	0.470	0.346	0.271	0.246	0.223	0.205	0.191	
China	Shihezi	0.668	0.564	0.457	0.344	0.266	0.239	0.219	0.202	0.189	
Russian Fed.	Petropavlovsk	0.654	0.551	0.445	0.337	0.260	0.234	0.210	0.195	0.181	
Russian Fed.	Magadan	0.643	0.541	0.434	0.324	0.259	0.227	0.207	0.189	0.175	
Egypt	Aswan	0.596	0.490	0.381	0.284	0.241	0.214	0.193	0.171	0.160	
Russian Fed.	Norilsk	0.560	0.451	0.346	0.262	0.229	0.207	0.186	0.170	0.154	
Russian Fed.	Vorkuta	0.569	0.462	0.357	0.266	0.234	0.208	0.186	0.170	0.155	
Saudi_Arabia	Jeddah	0.586	0.480	0.370	0.279	0.236	0.214	0.192	0.171	0.155	
Russian Fed.	Stakhanov	0.470	0.365	0.270	0.235	0.209	0.188	0.172	0.157		
US	Provo	0.770	0.687	0.554	0.383	0.333	0.307	0.289	0.276	0.264	
US	Garland	0.570	0.464	0.358	0.266	0.234	0.208	0.186	0.170	0.155	
US	Salt_Lake_City	0.569	0.462	0.357	0.266	0.234	0.208	0.186	0.170	0.155	
China	Korla	0.553	0.445	0.341	0.261	0.228	0.207	0.185	0.165	0.154	
US	Spokane	0.470	0.364	0.270	0.235	0.209	0.188	0.172	0.157		
China	Kuytun	0.441	0.337	0.256	0.228	0.203	0.182	0.167	0.152		
Yemen	Sana	0.711	0.534	0.421	0.248	0.203	0.19	0.139			

Afghanistan	Kabul	0.819	0.690	0.595	0.328	0.253	0.21	0.156	0.129
Russian Fed.	Frunze	0.805	0.710	0.563	0.297	0.251	0.21	0.154	0.128
Saudi_Arabia	Ta'if	0.552	0.351	0.237	0.195	0.148	0.13		
Ethiopia	Asmara	0.514	0.302	0.238	0.196	0.180	0.13		
Namibia	Windhoek	0.552	0.332	0.239	0.197	0.180	0.13		
Russian Fed.	Namangan	0.573	0.406	0.269	0.227	0.184	0.14	0.115	
China	Kashi	0.491	0.376	0.239	0.197	0.181	0.13		
Sudan	Kassala	0.305	0.267	0.224	0.183	0.134	0.12		
Iran	Mashhad	0.402	0.271	0.228	0.185	0.139	0.12		
China	Yining	0.478	0.273	0.231	0.190	0.143	0.13		
Afghanistan	Herat	0.432	0.267	0.225	0.183	0.134	0.12		
Iran	Sabzewar	0.346	0.268	0.226	0.184	0.135	0.12		
Russian Fed.	Osh	0.382	0.270	0.227	0.186	0.139	0.12		
Russian Fed.	Taldi-Kurgan	0.407	0.269	0.226	0.185	0.137	0.12		
Russian Fed.	Andizhan	0.318	0.266	0.224	0.182	0.135	0.11		
Russian Fed.	Alma-Ata	0.430	0.267	0.225	0.183	0.134	0.12		
Russian Fed.	Chita	0.387	0.270	0.228	0.186	0.137	0.12		
Russian Fed.	Zlatoust	0.303	0.239	0.195	0.181	0.132			
Russian Fed.	Fergana	0.290	0.232	0.191	0.144	0.126			
Russian Fed.	Bratsk	0.277	0.235	0.194	0.147	0.129			
Russian Fed.	Dzhambul	0.275	0.233	0.192	0.144	0.126			

TABLE A2-5

14/11GHz-band epfd limits for 3 m Antenna from Sensitive Links (1 dB Minimum Margin)

Antenna	**size =3m**												
	% Can't Exceed	**EPFD (dBW/m²/4KHz)**											
	99	*-189*	-190	-191	-192	-193	-194	-195	-196	-197	-198	-199	**-197**
	99.995	*-176*	-177	-178	-179	-180	-181	-182	-183	-184	-185	-186	**-185**
	100	*-173*	-174	-175	-176	-177	-178	-179	-180	-181	-182	-183	**-184**
Country	**City**	**Fraction of Unavailability due to NGSO**											
US	Denver	0.638	0.473	0.219	0.171	0.134							
China	Urumqi	0.972	0.925	0.885	0.853	0.826	0.736	0.582	0.362	0.302	0.292	0.285	
China	Yumen	0.968	0.922	0.883	0.850	0.825	0.729	0.575	0.359	0.294	0.286	0.279	
China	Uhai	0.904	0.869	0.840	0.799	0.703	0.596	0.475	0.296	0.212	0.200	0.191	
Saudi_Arabia	Riyadh	0.834	0.784	0.694	0.592	0.474	0.350	0.226	0.174	0.158	0.143	0.163	
Russian Fed.	Nakhodka	0.845	0.823	0.729	0.643	0.524	0.392	0.266	0.182	0.165	0.149		
China	Shihezi	0.841	0.812	0.717	0.627	0.513	0.380	0.252	0.177	0.160	0.149		
Russian Fed.	Petropavlovsk	0.837	0.798	0.706	0.609	0.494	0.366	0.241	0.175	0.159	0.148		
Russian Fed.	Magadan	0.835	0.787	0.697	0.596	0.478	0.353	0.230	0.174	0.158	0.147		
Egypt	Aswan	0.823	0.737	0.658	0.538	0.411	0.288	0.189	0.167	0.151	0.141		
Russian Fed.	Norilsk	0.794	0.705	0.612	0.503	0.372	0.250	0.176	0.160	0.149			
Russian Fed.	Vorkuta	0.803	0.712	0.623	0.512	0.380	0.257	0.181	0.161	0.150			
Saudi_Arabia	Jeddah	0.820	0.728	0.645	0.527	0.399	0.276	0.183	0.166	0.151	0.141		
Russian Fed.	Stakhanov	0.712	0.625	0.518	0.389	0.268	0.185	0.162	0.148	0.139			
US	Provo	0.883	0.852	0.827	0.747	0.664	0.537	0.405	0.275	0.188	0.175	0.163	
US	Garland	0.804	0.714	0.625	0.512	0.382	0.258	0.181	0.161	0.150			
US	Salt_Lake_City	0.803	0.712	0.623	0.511	0.380	0.258	0.181	0.161	0.150			

China	Korla	0.787	0.699	0.603	0.492	0.365	0.243	0.176	0.160	0.145
US	Spokane	0.710	0.624	0.515	0.389	0.267	0.181	0.162	0.148	0.139
China	Kuytun	0.688	0.585	0.477	0.358	0.236	0.176	0.157	0.147	
Yemen	Sana	0.881	0.838	0.816	0.686	0.533	0.224	0.176	0.139	
Afghanistan	Kabul	0.932	0.884	0.841	0.802	0.709	0.516	0.234	0.176	0.11
Russian Fed.	Frunze	0.932	0.878	0.839	0.808	0.661	0.424	0.345	0.174	0.11
Saudi_Arabia	Ta'if	0.820	0.780	0.678	0.483	0.214	0.161	0.125		
Ethiopia	Asmara	0.833	0.791	0.676	0.450	0.217	0.162	0.127		
Namibia	Windhoek	0.835	0.790	0.658	0.527	0.234	0.163	0.128		
Russian Fed.	Namangan	0.846	0.823	0.693	0.567	0.331	0.173	0.137		
China	Kashi	0.834	0.785	0.627	0.456	0.323	0.165	0.129		
Sudan	Kassala	0.814	0.659	0.501	0.222	0.170	0.133			
Iran	Mashhad	0.823	0.725	0.593	0.363	0.178	0.141			
China	Yining	0.814	0.753	0.631	0.440	0.206	0.149			
Afghanistan	Herat	0.810	0.650	0.488	0.222	0.170	0.133			
Iran	Sabzewar	0.815	0.708	0.447	0.303	0.172	0.134			
Russian Fed.	Osh	0.822	0.696	0.476	0.225	0.176	0.138			
Russian Fed.	Taldi-Kurgan	0.807	0.716	0.518	0.289	0.176	0.138			
Russian Fed.	Andizhan	0.801	0.686	0.540	0.250	0.169	0.133			
Russian Fed.	Alma-Ata	0.809	0.648	0.485	0.221	0.170	0.133			
Russian Fed.	Chita	0.824	0.700	0.485	0.238	0.176	0.138			
Russian Fed.	Zlatoust	0.796	0.680	0.485	0.271	0.165	0.129			
Russian Fed.	Fergana	0.736	0.571	0.450	0.205	0.149				
Russian Fed.	Bratsk	0.761	0.605	0.358	0.208	0.156	0.121			
Russian Fed.	Dzhambul	0.727	0.631	0.364	0.200	0.151				

TABLE A2-6

14/11GHz-band epfd limits for 7 m Antenna from Sensitive Links (1 dB Minimum Margin)

Antenna	**size =7m**											
	% Can't Exceed	**EPFD (dBW/m²/4KHz)**										
	99	*-197*	-198	-199	-200	-201	-202	-203	-204	-205	-206	**-203**
	99.999	*-181*	-182	-183	-184	-185	-186	-187	-188	-189	-190	**-191**
	100	*-180*	-181	-182	-183	-184	-185	-186	-187	-188	-189	**-190**
Country	**City**	**Fraction of Unavailability due to NGSO**										
US	Denver	0.198	0.164	0.102								
China	Urumqi	1.000	1.000	1.000	1.000	0.722	0.550	0.402	0.279	0.179	0.125	
China	Yumen	1.000	1.000	1.000	1.000	0.709	0.539	0.393	0.272	0.174	0.122	
China	Uhai	1.000	1.000	0.813	0.636	0.482	0.351	0.240	0.150	0.123		
Saudi_Arabia	Riyadh	0.741	0.584	0.447	0.330	0.230	0.149	0.122				
Russian Fed.	Nakhodka	0.824	0.656	0.508	0.380	0.271	0.180	0.122				
China	Shihezi	0.796	0.632	0.488	0.363	0.257	0.169	0.123				
Russian Fed.	Petropavlovsk	0.770	0.608	0.468	0.346	0.244	0.159	0.121				
Russian Fed.	Magadan	0.748	0.590	0.452	0.333	0.233	0.151	0.120				
Egypt	Aswan	0.650	0.508	0.384	0.277	0.188	0.123					
Russian Fed.	Norilsk	0.588	0.456	0.340	0.242	0.161	0.122					
Russian Fed.	Vorkuta	0.603	0.467	0.349	0.250	0.167	0.122					

Saudi_Arabia	Jeddah	0.631	0.493	0.371	0.267	0.180	0.123		
Russian Fed.	Stakhanov	0.453	0.343	0.248	0.168	0.122			
US	Provo	1.000	0.894	0.709	0.546	0.408	0.289	0.192	0.124
US	Garland	0.604	0.469	0.352	0.251	0.168	0.122		
US	Salt_Lake_City	0.603	0.467	0.350	0.250	0.167	0.122		
China	Korla	0.575	0.445	0.332	0.235	0.155	0.122		
US	Spokane	0.451	0.341	0.246	0.167	0.121			
China	Kuytun	0.410	0.307	0.219	0.146	0.120			
Yemen	Sana	1.000	0.695	0.501	0.22	0.2	0.121		
Afghanistan	Kabul	1.000	1.000	0.723	0.29	0.23	0.197	0.118	
Russian Fed.	Frunze	1.000	1.000	0.732	0.47	0.22	0.195	0.113	
Saudi_Arabia	Ta'if	0.463	0.237	0.234	0.16				
Ethiopia	Asmara	0.612	0.241	0.205	0.16	0.1			
Namibia	Windhoek	0.605	0.376	0.206	0.16	0.1			
Russian Fed.	Namangan	0.724	0.266	0.296	0.19	0.11			
China	Kashi	0.535	0.453	0.206	0.17	0.1			
Sudan	Kassala	0.361	0.202	0.170	0.11				
Iran	Mashhad	0.351	0.215	0.195	0.12				
China	Yining	0.518	0.223	0.199	0.14				
Afghanistan	Herat	0.264	0.232	0.169	0.1				
Iran	Sabzewar	0.246	0.204	0.175	0.11				
Russian Fed.	Osh	0.253	0.304	0.180	0.11				
Russian Fed.	Taldi-Kurgan	0.463	0.213	0.185	0.12				
Russian Fed.	Andizhan	0.332	0.208	0.169	0.12				
Russian Fed.	Alma-Ata	0.244	0.213	0.168	0.1				
Russian Fed.	Chita	0.254	0.208	0.181	0.11				
Russian Fed.	Zlatoust	0.234	0.203	0.161	0.1				
Russian Fed.	Fergana	0.215	0.192	0.133					
Russian Fed.	Bratsk	0.221	0.194	0.142					
Russian Fed.	Dzhambul	0.216	0.191	0.132					

TABLE A2-7

14/11GHz-band epfd limits for 10 m Antenna from Sensitive Links (1 dB Minimum Margin)

Antenna	**size =10m**											
	% Can't Exceed	**EPFD (dBW/m²/4KHz)**										
	99	*-200*	-201	-202	-203	-204	-205	-206	-207	-208	-209	**-206**
	99.999	*-185*	-186	-187	-188	-189	-190	-191	-192	-193	-194	**-194**
	100	*-183*	-184	-185	-186	-187	-188	-189	-190	-191	-192	**-193**
Country	**City**	**Fraction of Unavailability due to NGSO**										
US	Denver	0.174	0.120	0.109								
China	Urumqi	1.000	1.000	1.000	0.747	0.572	0.420	0.293	0.190	0.126	0.124	
China	Yumen	1.000	1.000	1.000	0.734	0.560	0.411	0.286	0.184	0.127	0.125	
China	Uhai	1.000	0.841	0.660	0.501	0.366	0.252	0.161	0.127	0.123		
Saudi_Arabia	Riyadh	0.607	0.464	0.344	0.242	0.157	0.125	0.122				
Russian Fed.	Nakhodka	0.678	0.528	0.396	0.282	0.190	0.128	0.122				
China	Shihezi	0.654	0.506	0.379	0.270	0.179	0.127	0.124				

Russian Fed.	Petropavlovsk	0.632	0.485	0.362	0.256	0.168	0.125	0.123		
Russian Fed.	Magadan	0.612	0.470	0.349	0.246	0.160	0.124	0.123		
Egypt	Aswan	0.526	0.400	0.291	0.199	0.127	0.123	0.120		
Russian Fed.	Norilsk	0.473	0.354	0.254	0.169	0.125	0.121			
Russian Fed.	Vorkuta	0.485	0.364	0.262	0.177	0.127	0.124			
Saudi_Arabia	Jeddah	0.510	0.387	0.280	0.191	0.127	0.124			
Russian Fed.	Stakhanov	0.356	0.258	0.177	0.125	0.122				
US	Provo	1.000	0.734	0.567	0.424	0.304	0.203	0.130	0.123	0.120
US	Garland	0.488	0.367	0.264	0.177	0.126	0.123			
US	Salt_Lake_City	0.486	0.365	0.262	0.177	0.127	0.121			
China	Korla	0.462	0.345	0.246	0.164	0.126	0.122			
US	Spokane	0.356	0.257	0.176	0.126	0.123				
China	Kuytun	0.320	0.230	0.155	0.125	0.122				
Yemen	Sana	0.795	0.299	0.233	0.198	0.137	0.111			
Afghanistan	Kabul	1.000	0.781	0.309	0.235	0.204	0.139			
Russian Fed.	Frunze	1.000	0.780	0.449	0.344	0.202	0.136	0.11		
Saudi_Arabia	Ta'if	0.250	0.286	0.169	0.113					
Ethiopia	Asmara	0.273	0.211	0.171	0.116					
Namibia	Windhoek	0.457	0.278	0.175	0.118					
Russian Fed.	Namangan	0.444	0.223	0.194	0.133	0.109				
China	Kashi	0.258	0.292	0.178	0.122					
Sudan	Kassala	0.212	0.180	0.125	0.111					
Iran	Mashhad	0.296	0.198	0.138	0.101					
China	Yining	0.229	0.203	0.150	0.114					
Afghanistan	Herat	0.211	0.179	0.125	0.108					
Iran	Sabzewar	0.236	0.184	0.128	0.108					
Russian Fed.	Osh	0.216	0.191	0.134	0.108					
Russian Fed.	Taldi-Kurgan	0.217	0.196	0.133	0.114					
Russian Fed.	Andizhan	0.213	0.184	0.125	0.101					
Russian Fed.	Alma-Ata	0.211	0.183	0.125	0.108					
Russian Fed.	Chita	0.217	0.192	0.134	0.109					
Russian Fed.	Zlatoust	0.257	0.173	0.118	0.107					
Russian Fed.	Fergana	0.196	0.145	0.108						
Russian Fed.	Bratsk	0.200	0.157	0.108						
Russian Fed.	Dzhambul	0.195	0.147	0.103						

TABLE A2-8

14/11GHz-band apfd limits for 3 Degree beamwidth from Sensitive Links (1 dB Minimum Margin and 99.99% Availability)

Beamwidth	**=3 degrees**							
	% Can't Exceed	**APFD (dBW/m^2/4KHz)**						
	100	-171	-172	-173	-174	-175	-176	-177
Country	**City**	**Fraction of unavailability due to NGSO**						
China	Urumqi	0.173	0.157	0.112				
China	Yumen	0.170	0.153	0.142	0.129			
China	Uhai	0.149	0.136	0.127	0.119	0.114		
Saudi_Arabia	Riyadh	0.123	0.116	0.110				

Russian Fed.	Nakhodka	0.155	0.144	0.131	0.125	0.118	0.112
China	Shihezi	0.128	0.121	0.116	0.103		
Russian Fed.	Petropavlovsk	0.130	0.123	0.115	0.109		
Russian Fed.	Magadan	0.132	0.124	0.117	0.113		
Egypt	Aswan	0.118	0.113				
Russian Fed.	Norilsk	0.133	0.124	0.118	0.114		
Russian Fed.	Vorkuta	0.131	0.124	0.117	0.111		
Saudi_Arabia	Jeddah	0.118	0.112				
Russian Fed.	Stakhanov	0.128	0.121	0.116	0.105		
US	Provo	0.143	0.132	0.125	0.116	0.112	
US	Ogden	0.115	0.112				
US	Salt_Lake_City	0.119	0.115	0.100			
China	Korla	0.118	0.113				
US	Spokane	0.114	0.103				
China	Kuytun	0.113					
Yemen	Sana	0.118	0.112				
Afghanistan	Kabul	0.127	0.120	0.114			
Russian Fed.	Frunze	0.128	0.120	0.115	0.103		
Russian Fed.	Namangan	0.114					
China	Kashi	0.111					
China	Yining	0.103					
Russian Fed.	Chita	0.103					

TABLE A2-9

14/11GHz-band apfd limits for 2 Degree beamwidth from Sensitive Links (1 dB Minimum Margin and 99.99% Availability)

Beamwidth	**=2 degrees**						
	% Can't Exceed	**APFD (dBW/m²/4KHz)**					
	100	-176	-177	-178	-179	-180	**-181**
Country	**City**	**Fraction of unavailability due to NGSO**					
China	Urumqi	0.140					
China	Yumen	0.148	0.134	0.115			
China	Uhai	0.130	0.124	0.115	0.109	0.109	
Saudi_Arabia	Riyadh	0.114					
Russian Fed.	Nakhodka	0.137	0.126	0.121	0.113	0.113	
China	Shihezi	0.118	0.112				
Russian Fed.	Petropavlovsk	0.118	0.114				
Russian Fed.	Magadan	0.122	0.114	0.101			
Egypt	Aswan	0.108					
Russian Fed.	Norilsk	0.122	0.115	0.107			
Russian Fed.	Vorkuta	0.119	0.114	0.100			
Saudi_Arabia	Jeddah	0.104					
Russian Fed.	Stakhanov	0.119	0.113				
US	Provo	0.128	0.119	0.116			
US	Salt_Lake_City	0.111					
China	Korla	0.109					
Afghanistan	Kabul	0.117	0.111				

Russian Fed.	Frunze	0.118	0.112

TABLE A2-10

14/11GHz-band apfd limits for 1 Degree beamwidth from Sensitive Links (1 dB Minimum Margin and 99.99% Availability)

Beamwidth	**=1 degree**							
	% Can't Exceed			**APFD (dBW/m^2/4KHz)**				
	100	-181	-182	-183	-184	-185	**-186**
Country	**City**	**Fraction of unavailability due to NGSO**					
China	Urumqi	0.166	0.147				
China	Yumen	0.163	0.147	0.137	0.123		
China	Uhai	0.141	0.133	0.124	0.118	0.109	
Saudi_Arabia	Riyadh	0.118	0.113				
Russian Fed.	Nakhodka	0.151	0.137	0.129	0.121	0.113	
China	Shihezi	0.125	0.118	0.112			
Russian Fed.	Petropavlovsk	0.126	0.120	0.114			
Russian Fed.	Magadan	0.129	0.121	0.116	0.105		
Egypt	Aswan	0.116	0.108				
Russian Fed.	Norilsk	0.130	0.122	0.114	0.107		
Russian Fed.	Vorkuta	0.127	0.121	0.113	0.101		
Saudi_Arabia	Jeddah	0.115	0.104				
Russian Fed.	Stakhanov	0.124	0.118	0.113			
US	Provo	0.137	0.128	0.122	0.116		
US	Ogden	0.115					
US	Salt_Lake_City	0.117	0.111				
China	Korla	0.115	0.109				
US	Spokane	0.114					
China	Kuytun	0.106					
Yemen	Sana	0.115	0.103				
Afghanistan	Kabul	0.124	0.117	0.111			
Russian Fed.	Frunze	0.124	0.118	0.112			
Russian Fed.	Namangan	0.107					
Russian Fed.	Dzhambul						

ANNEX 3

CANDIDATE INPUT EPFD LIMITS THAT PROTECT GSO FSS SYSTEMS DEVELOPED USING GENERIC TRANSMISSION PARAMETERS IN THE 10/12 GHz SHARED BANDS

The methodology presented in Documents 4A/21, 4A/TEMP/36, 4-9-11/40 and 4-9-11/103 is applied here toward proposing replacements for the WRC-97 provisional epfd limits. The methodology uses generic transmission parameters and an application of ITU-R S.1323 Method B to calculate the candidate input epfd limits. The transmission parameters used are from Document 4-9-11/TEMP/29[1] and are based on the existing and future technology. Performance margins are based on defining the links that are most sensitive to interference, that is those requiring the smallest clear sky margins. With this approach most GSO systems will be protected and the flexibility to develop and implement future technology will not be inhibited. All candidate input epfd limits and percentages of time not to exceed are single entry values.

1 Overall Principles for Determining the Candidate Input Epfd Limits

The selection of pfd limits to protect GSO/FSS networks must take into account a generic range of link characteristics for both existing and planned networks. The limits must allow evolutionary technological improvement of GSO FSS satellite and earth station receivers, particularly at the higher frequencies.

Precedent has allowed the introduction of additional GSO networks into the allocated FSS bands without coordination provided that interference from a single network increases system noise temperatures by no more than 6%. It has been accepted through the application of ITU-R recommendations, such as ITU-R S.1323, and by system designers that a system should be designed to accept total interference from all other possible GSO/FSS networks that would result in a system noise temperature increase less than 20%.

Interference from non-GSO/FSS networks differs from that of GSO/FSS networks in that it is of a time-varying nature and not steady state as that of interfering GSO/FSS networks. Accordingly, it is reasonable to consider interference from non-GSOs to constitute two segments, that which contributes to the GSO networks during their periods of "long term" availability and that which contributes to the "short term" unavailability. On that basis, it would appear consistent to allow non-GSO/FSS networks to share spectrum with GSO networks provided that each non-GSO network will limit its effect on any GSO network system noise temperature to a system noise increase of an aggregate of 6% divided by the number of NGSO systems during the full period of "long term" link availability of the GSO network. WRC-97 chose this approach; however, it is sufficient to allow the long term percent time not to exceed to be 99.0%. Furthermore, the total effect of multiple non-GSO networks operating in the same band should not increase any GSO network's system noise temperature by more than 6% during its

[1] In this Document the 4-9-11/Temp/29 Clear Sky Margins are revised to include the earth stations receive system noise temperature increase due to rain.

availability period or 99.0% of time. Therefore, the single entry increase in system noise temperature should be less than 6% divided by the number of NGSO networks which can share the same frequency. Following further study, it may also be appropriate to reduce the percentage of time not to exceed to a value below 99.0%. Previous studies and Recommendation ITU-R S.1323 indicate that all non-GSO networks sharing the band should contribute no more than an aggregate 10% to the "short term" link unavailability period of any GSO network. Therefore, for the single entry limits a single non-GSO network should contribute no more than 10% divided by N to the "short term" link unavailability period of any GSO network.

2 Methodology and Key Parameters

The methodology is based on Method B of Recommendation ITU-R S.1323. Although Method B can underestimate interference it is more accurate than current computational implementations of ITU-R S.1323 Method A which produce estimates that are sensitive to modeling assumptions needed to simplify the Method A calculations. These assumptions can produce arbitrary results which may lead to inaccurate interference estimates. Method B calculations are much easier to apply and are more consistent. Also, Method B will produce reasonably accurate estimates of permissible interference in rain regions where significant rain fades occur infrequently relative to interference events. These are the rain regions where GSO FSS systems operate with small rain fade margins and therefore are most sensitive to NGSO FSS short term interference. The transmission parameters used in this study are based on systems that operate or will operate in low rain fade regions.

Values for the epfd limits necessary to protect GSO FSS systems from single entry NGSO FSS interference are calculated in JTG 4-9-11/103 and used in the following sections to review the provisional WRC-97 epfd limits and propose new limits. The calculated values for epfd limits from Doc. 4-9-11/103 are based on specific system parameters and are presented in Table A3-1. The rain fade margins and link availability values are presented in Table A3-2. Rain fade margins are calculated using the parameters presented in Table A3-3. This represents GSO FSS links most sensitive to interference and thus a worst case situation.

TABLE A3-1 10/12 GHZ BAND PARAMETERS

Parameter	Value
Earth Station Antenna Efficiency	72%
Earth Station System Noise Temperature, Sys	150 K at 11.82 GHz
Interference from Other GSOs	20%
Permissible Downlink Long Term Interference	<6%
Percentage of Time that Long Term Interference cannot be Exceeded	99.0%
Rain Margin, M_r	Determined using ITU-R 618-5
Allowable Degradation	M_r
Percentage of Time that Allowable Degradation cannot be exceeded	1-0.1(1-A)/N where 1-A=rain outage N = number of NGSO systems, seven for this study

Margin Above Sync Loss, K	2 dB
Maximum Allowable Degradation	M_r +K or M_r+2 dB
Percentage of Time that Maximum Degradation cannot be exceeded	100%

TABLE A3-2

Link Availability and Rain Margin at 12 GHz

Earth Station Receive Antenna Diameter (m)	Link Availability (%)	Rain Margin (dB)	Rain Model/Region
0.6	99.7	1.0	
1.0	99.8	1.2	
1.8	99.9	1.6	
2.4	99.95	2.2	ITU-R 618-5/Denver
4.5	99.99	4.1	
10	99.99	4.1	
11	99.99	4.1	

TABLE A3-3

Rain Model Parameters

Parameter	Value
Rain Model	ITU-R 618-5
Satellite Location	101 W deg.
City/ITU Region	Denver(USA)/E
Altitude	1.61 Km
Latitude	39.73 N deg
Longitude	104 W deg.
Elevation Angle	43.2 deg.

The value for N, the number of NGSOs that can share a frequency band, is seven. This value is based on the number of operators that have applied to the US administration for NGSO networks. It is expected that the same number or more will apply for 14/11GHz-band networks when the US administration opens a filing window. Also, Doc 4-9-11/133 has demonstrated that at least seven NGSO FSS systems can operate co-frequency using spatial isolation.

The methodology is summarized as follows.

Input Data

1) Link availability (A) requirement for each terminal antenna size

2) Location of terminal and satellite

3) Rain region or city to be served

Steps

1) Calculate the rain fade margin (Mr) required to meet the link availability for a particular link. This term is equivalent to zt of ITU-R S.1323 Method B since the difference between clear sky C/N and required C/N is the margin needed to overcome rain fades.

2) Determine the unavailability (1-A) as the percentage of the year that the BER can exceed the required BER. This is equivalent in Method B to p, the percent of year[2] that a required BER can be exceeded.

3) Calculate the percent of time not to exceed an interference level for a given terminal size and availability as,

$$1-(0.1/N)(1-A)$$

Where N= number of NGSO satellite systems
N=7 in this study

This is the allowable outage that an NGSO FSS system can contribute to the link outage of the GSO FSS as described in Method B.

4) Relate Mr to the degradation that when exceeded results in an outage which adds to the unavailability of the satellite link, and therefore cannot be exceeded more than 1-(0.1/N) (1-A).

5) Either by applying equation 1 of Document 4-9-11/103-E Annex D or using the data provided in Tables 2-1 through 2-3, the degradation for an apfd or epfd value can be determined and associated with the calculated percent of time that the degradation (rain margin, Mr) cannot be exceeded.

Section 6 of Document 4-9-11/103 Annex D provides a detailed description of this methodology and presents example results for long term, short term, and never to exceed epfd limits.

3 Summary of Candidate Input PFD Limit Calculation for the 10/12 GHz Frequency Bands

Using the above principles and the methodology of Document 4-9-11/103-E Annex D, epfd limits that protect GSO FSS networks for the downlink were generated. The limits generated are single entry

[2] The S.1323 Method B "p" is based on a time interval of a year. Satellite systems can adjust power to obtain seasonal rain margins. In some cases it may be appropriate to use p, or link availability, to be based on a month time interval.

assuming seven NGSO FSS systems. Each epfd limit is based on the ΔT/T (noise degradation) interference criterion that is associated with a percent of time not to exceed. Link parameters such as system noise temperature, percentage of noise from other GSO networks, and antenna efficiency are presented. Epfd limits were calculated for a range of earth antenna diameters. G/T values are presented for each antenna diameter for epfd.

4 Candidate Input NGSO FSS 10/12 GHz epfd Limits

Values for NGSO FSS epfd limits were determined using the method described in Document 4-9-11/103-E Annex D and the parameters presented in Tables A3-1 through A3-2. These epfd limits are presented in Annex 3-A based on a long term aggregate interference criterion of 6%. The short term limits were calculated, according to the methodology of Document 4-9-11/103, using the link margins and link availability presented in Table A3-2. The limits presented are for single entry interference only, and are proposed as NGSO FSS epfd limits to replace the limits accepted on a provisional basis by WRC-97.

Table A3-4 summarizes the candidate input epfd limits contained in Annex 3-A and compares them to the provisional epfd limits from WRC-97 Resolution 130. The candidate input limits are those necessary to adequately protect GSO FSS systems from single entry NGSO FSS interference, under the assumptions made in Section 2. Most of the WRC-97 provisional limits fail to provide sufficient protection.

TABLE A3-4

Candidate Input vs. Provisional 10/12 GHz Frequency Band epfd Limits

Frequency Band (GHz)	WRC-97 Provisional EPFD Limits			Candidate Input EPFD Limits for Aggregate (N=1) Case
	epfd dB(W/m²/4KHz)	Percent of Time Not to Exceed (%)	Antenna Diameter (m)	From Table 3-A1 (for % of time not to exceed)
10.7-11.7	-179	99.7	0.6	- 176(99)
11.2-12.2 (Region 2)	-192 -186	99.9 99.97	3 3	- 189(99) - 189(99)
12.2-12.5 in Region 3	-195 -170	99.97 99.999	10 0.6	- 200(99) -163(100)
12.5-12.75 in Regions 1 and 3	-173 -178 -170	99.999 99.999 100	3 10 ≥0.6[1]	-176(99.995) -185(99.999) -183(100)[1]

Note 1: The antenna size considered ranges from diameters of 0.6 m to 11 m. To determine the epfd limits the 11 m diameter antenna is used. The WRC-97 specification is not consistent with the need to

protect 11 meter antennas as a case greater than 0.6 meter, and so fails to protect GSO FSS systems using larger antennas from NGSO FSS interference.

6 Summary

This study uses a methodology which is an application of ITU-R S.1323 Method B to determine interference criteria and thus calculate NGSO FSS epfd limits necessary to adequately protect GSO FSS systems from single entry interference caused by NGSO networks. Also, this methodology allows an assessment of GSO FSS noise degradation that would result from each of the WRC-97 provisional epfd limit values. Generic satellite transmission parameters are used to provide protection of a broad range of GSO FSS systems. Through the use of generic parameters GSO FSS system operation and implementation flexibility are maintained.

Table A3-A1 of Annex 3-A presents candidate input epfd limits that sufficiently protect GSO FSS systems from NGSO FSS interference for the aggregate (N=1) case, while Tables A3-A2 through A3-A4 present representative epfd limits assuming N=3, 5, and 7, respectively.

ANNEX 3-A

12 GHz epfd Limits

The following Tables present NGSO FSS epfd limits calculated using the methodology presented in Document 4-9-11/103 Annex D.

TABLE A3-A1

Candidate Input Downlink epfd Limits on NGSO FSS to Protect GSO FSS for N=1 (Aggregate) at 11.7 to 12.2 GHz

Earth Station Receive Antenna Size (m)	epfd Limit on NGSO to Protect GSO dB(W/m^2/4KHz)	Percent of Time Value is Not to be Exceeded (%)
0.6	-176	99.0
1.0	-181	99.0
1.2	-181	99.0
1.8	-185	99.0
2.4	-187	99.0
3.0	-189	99.0
4.5	-192	99.0
7.0	-197	99.0
10	-200	99.0
11	-200	99.0
0.6	-169	99.97

1.0	-172	99.98
1.2	-174	99.98
1.8	-176	99.99
2.4	-176	99.995
3.0	-176	99.995
4.5	-178	99.999
7.0	-181	99.999
10	-185	99.999
11	-186	99.999
0.6	-163	100
1.2	-168	100
1.8	-171	100
3.0	-173	100
7.0	-180	100
10	-183	100
11	-183	100

TABLE A3-A2

Representative Downlink epfd Limits on NGSO FSS to Protect GSO FSS for N=3 at 11.7 to 12.2 GHz

Earth Station Receive Antenna Size (m)	epfd Limit on NGSO to Protect GSO dB(W/m²/4KHz)	Percent of Time Value is Not to be Exceeded (%)
0.6	-180	99.0
1.0	-185	99.0
1.8	-189	99.0
2.4	-192	99.0
4.5	-197	99.0
10	-204	99.0
11	-207	99.0
0.6	-169	99.99
1.0	-172	99.993
1.8	-176	99.997
2.4	-176	99.998
4.5	-178	99.9997
10	-185	99.9997
11	-186	99.9997
0.6	-163	100
1.8	-174	100
11	-183	100

TABLE A3-A3

Representative Downlink epfd Limits on NGSO FSS to Protect GSO FSS for N=5 at 11.7 to 12.2 GHz

Earth Station Receive Antenna Size (m)	epfd Limit on NGSO to Protect GSO dB(W/m²/4KHz)	Percent of Time Value is Not to be Exceeded (%)
0.6	-182	99.0
1.0	-187	99.0
1.8	-192	99.0
2.4	-194	99.0
4.5	-199	99.0
10	-206	99.0
11	-207	99.0
0.6	-169	99.994
1.0	-172	99.996
1.8	-176	99.998
2.4	-176	99.999

4.5	-178	99.9998
10	-185	99.9998
11	-186	99.9998
0.6	-163	100
1.8	-174	100
11	-183	100

TABLE A3-A4

Representative Downlink epfd Limits on NGSO FSS to Protect GSO FSS for N=7 at 11.7 to 12.2 GHz

Earth Station Receive Antenna Size (m)	epfd Limit on NGSO to Protect GSO dB(W/m^2/4KHz)	Percent of Time Value is Not to be Exceeded (%)
0.6	-184	99.0
1.0	-188	99.0
1.8	-193	99.0
2.4	-195	99.0
4.5	-201	99.0
10	-208	99.0
11	-208	99.0
0.6	-169	99.996
1.0	-172	99.997
1.8	-176	99.999
2.4	-176	99.9993
4.5	-178	99.9999
10	-185	99.9999
11	-186	99.9999
0.6	-163	100
1.8	-174	100
11	-183	100

ANNEX 4

CANDIDATE INPUT APFD LIMITS THAT PROTECT GSO FSS SYSTEMS DEVELOPED USING GENERIC TRANSMISSION PARAMETERS IN THE 12/14 GHz SHARED BANDS

The methodology presented in Documents 4A/23-E, 4-9-11/40 and 4-9-11/103 is applied here toward reviewing and proposing replacements for the WRC-97 provisional apfd limits. The methodology uses generic transmission parameters and an application of ITU-R S.1323 Method B to calculate the candidate input apfd limits. The transmission parameters used are based on the existing and future technology and presented in Document 4-9-11/Temp/23. All candidate input apfd limits are single entry values.

1 Overall Principles and Methodology for Determining the Candidate Input Apfd Limits

Precedent has allowed the introduction of additional GSO networks into the allocated FSS bands without coordination provided that interference from a single network increases system noise temperatures by no more than 6%. It has been accepted through the application of ITU-R recommendations, such as ITU-R S.1323, and by system designers that a system should be designed to accept total interference from all other possible GSO/FSS networks that would result in a system noise temperature increase less than 20%. In Article S22 of the Radio Regulations and Resolution 130 apfd limits are associated with a percentage of time during which the apfd level may not be exceeded of 100%. On the bases of this consideration and the GSO network interference level precedent, it would appear consistent that uplink interference should not exceed 6% of the system noise temperature for 100% of the time. In order to limit the impact of uplink interference on the downlink, the uplink interference criteria should not exceed the downlink interference limit.

The methodology and equations used to calculate apfd values is presented in Document 4-9-11/103 Annex D. The methodology is based on Method B of Recommendation ITU-R S.1323.

Values for the apfd limits necessary to protect GSO FSS systems from single entry NGSO FSS interference are calculated in JTG 4-9-11/103 and used in the following sections to review the provisional WRC-97 apfd limits and propose new limits. The calculated values for apfd limits from JTG 4-9-11/103 are based on specific system parameters and are presented in Table A4-1.

The calculations assume a value for N, the number of NGSOs that can share a frequency band, of seven. This value is based on the number of operators that have applied to the US administration for NGSO networks. It is expected that the same number or more will apply for 14/11GHz-band networks if the US administration opens a filing window. Therefore, the uplink interference from any one NGSO system should not exceed 6/N% of the system noise temperature for 100% of the time. For N=7, this level is approximately 0.9%.

TABLE A4-1

12/14 GHz Band Parameters

Parameter	Value
Satellite Antenna Efficiency	62%
Satellite System Noise Temperature, T_{sys}	500K
Permissible Uplink Long Term Interference, $\Delta T/T$	<6%
Maximum Allowable Uplink Degradation	<0.25 dB

2 Summary of Candidate Input PFD Limit Calculation for the 12/14 GHz Frequency Bands

Using the above principles and the methodology of Document 4-9-11/103-E Annex D, apfd limits that protect GSO FSS networks for the uplink were generated. The limits generated are single entry assuming seven NGSO FSS systems. The apfd limits were calculated for a receive noise temperature of 500°K and a range of satellite receive antenna gains. Link parameters such as system noise temperature, percentage of noise from other GSO networks, and antenna efficiency are presented. G/T values are presented for each beamwidth for apfd. Although currently 12/14 GHz one degree satellite beams are not typical, today's technology can produce GSO FSS satellites with multiple beams with one degree coverage using on board signal processing. The apfd limits that are to protect GSO FSS networks should take into account beamwidths of one degree so as not to constrain the application of these smaller beamwidths.

3 Candidate Input NGSO FSS 12/14 GHz apfd Limits

Values for NGSO FSS apfd limits were determined using the method described in Document 4-9-11/103 Annex D and the parameters presented in Table A4-1. These apfd limits are presented in Annex 4-A based on an aggregate interference criterion of 6% increase in system noise temperature. The limits presented are for single entry interference only, and are proposed as NGSO FSS apfd limits to replace the limits accepted on a provisional basis by WRC-97.

WRC-97 designated provisional apfd limits specified in RR S22.5 but did not specify the beamwidth to be used when determining the interference into a GSO FSS satellite receiver. 12/14 GHz GSO satellites must be protected for a variety of coverage's which require a range of beamwidths. Annex 4-A presents apfd limits necessary for adequate protection of GSO FSS systems from NGSO FSS uplink interference, for GSO satellite beamwidths of 1, 2, 3, and 5 degrees.

4 Summary

This study uses a methodology which is an application of ITU-R S.1323 Method B to determine interference criteria and thus calculate NGSO FSS apfd limits necessary to adequately protect GSO FSS systems from single entry interference caused by NGSO networks. Also, this methodology allows an assessment of GSO FSS noise degradation that would result from each of the WRC-97 provisional apfd limit values. Generic satellite transmission parameters are used to provide protection of a broad range of GSO FSS systems. Also, through the use of generic parameters GSO FSS system operation and implementation flexibility are maintained.

Table A4-A1 of Annex 4-A presents candidate input apfd limits that sufficiently protect GSO FSS systems from NGSO FSS interference for the aggregate (N=1) case, while Tables A4-A2 through A4-A4 present representative apfd limits assuming N=3, 5, and 7, respectively.

ANNEX 4-A

14 GHz APFD Limits Using Criterion of ΔT/T of 6%

The following Tables present NGSO FSS apfd limits calculated using the methodology presented in Document 4-9-11/103-E Annex D.

TABLE A4-A1

Candidate Input Uplink apfd Limits on NGSO FSS to Protect GSO FSS for N=1 (Aggregate) at 13.75 to 14.5 GHz

Satellite Receive Antenna Beamwidth (degrees)	apfd Limit on NGSO to Protect GSO dB(W/m^2/4KHz)	Percent of Time Value is Not to be Exceeded (%)
1	-166	100
2	-151	100
3	-156	100
5	-163	100

TABLE A4-A2

Representative Uplink apfd Limits on NGSO FSS to Protect GSO FSS for N=3 at 13.75 to 14.5 GHz

Satellite Receive Antenna Beamwidth (degrees)	apfd Limit on NGSO to Protect GSO dB(W/m^2/4KHz)	Percent of Time Value is Not to be Exceeded (%)
1	-182	100
2	-176	100
3	-172	100
5	-168	100

TABLE A4-A3

Representative Uplink apfd Limits on NGSO FSS to Protect GSO FSS for N=5 at 13.75 to 14.5 GHz

Satellite Receive Antenna Beamwidth (degrees)	apfd Limit on NGSO to Protect GSO dB(W/m^2/4KHz)	Percent of Time Value is Not to be Exceeded (%)
1	-184	100
2	-178	100
3	-175	100
5	-170	100

TABLE A4-A4

Representative Uplink apfd Limits on NGSO FSS to Protect GSO FSS for N=7 at 13.75 to 14.5 GHz

Satellite Receive Antenna Beamwidth (degrees)	apfd Limit on NGSO to Protect GSO dB(W/m^2/4KHz)	Percent of Time Value is Not to be Exceeded (%)
1	-186	100
2	-180	100
3	-176	100
5	-172	100

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Delayed Contribution
Addendum 2 to
Document 4-9-11/342-E
Long Beach, 25 January 1999
Original: English only

United States of America

PROPOSED REVISION TO RESOLUTION 130 PROVISIONAL EPFD AND APFD LIMITS IN THE RESOLUTION 130 14/11 GHZ BANDS

Attached are the USA proposed epfd levels for the 14/11 GHz band.

USA Proposed Aggregate 14/11GHz Band epfd Limits

	Proposed Aggregate NGSO system EPFD limits	
Antenna Diameter (m)	EPFD ($dBW/m^2/4KHz$)	Percent of time not to exceed (%)
0.6	-183	99
0.6	-173	99.97
0.6	-170	100
1.2	-188	99
1.2	-182	99.98
1.2	-170	100
1.8	-192	99
1.8	-185	99.99
1.8	-170	100
3	-196	99
3	-186	99.995
3	-172	100
7	-200	99
7	-183	99.999
7	-174	100
10	-200	99.97
10	-183	99.999
10	-176	100

INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION STUDY GROUPS

Delayed Contribution
Corrigendum 1 to
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United States of America

PROPOSED RESOLUTION 130 PROVISIONAL EPFD AND APFD LIMITS IN THE RESOLUTION 130 14/11GHz BANDS

1. The following two paragraphs are to be added after the fourth paragraph on the first page of the document:

Note that failing the 10% criteria does not necessarily preclude the use of the GSO link. However, violating the criteria may require the GSO link to use more satellite or earth station resources to overcome the additional interference.

Due to the fact that some NGSO systems may view these results as constraining, the JTG may need to consider not ensuring protection in accordance with S.1323 of the links considered in this paper to earth stations in some climatic regions.

This document provides a parametric analysis so that tradeoffs can be studied. The JTG should consider the impact on GSOs and the impact on NGSOs.